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(Italy)

ON THE QUESTION OF GOODS (FREIGHT) STATIONS (SUBJECT X FOR DISCUSSION AT THE NINTH CONGRESS OF THE INTERNATIONAL RAILWAY ASSOCIATION), (1)

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Figs. 1 à 11, p. 6 to 17.

Goods station.

Amongst the numerous different and even divergent problems that require to be studied and solved by those responsible for railway working, the questions relating to the organization of goods traffic are always of great importance.

The goods traffic is in general the most important source of revenue, it also has a great bearing on social questions. Hence the necessity, particularly when the State is the controlling party, for combining the various requirements of the working in order that the goods traffic may be carried out in a simple, rapid, safe and economical manner, and at the same time that it may assist industries, agriculture, and the supply of provisions to large cities. The concentration of people in large centres and the creation of great modern industries have produced vast volumes of incoming and out-going traffic at certain definite places. This causes numerous technical difficulties to arise if all the services necessary for these great transport movements are to carry on their work with regularity.

In order to meet these requirements the first step taken was that of establishing a goods department in the railway stations quite separate from those dealing with the passenger traffic. The mixing of the passenger service with the goods service gives rise to considerable disadvantages owing to the fact that the two classes of traffic are entirely different in their requirements and growth.

The increasing magnitude of goods transport has even sometimes rendered inadequate those arrangements which were created specially for this class of traffic, independently of the facilities provided for passenger traffic. The consequence of this led to the construction of goods stations properly so called, that is to say stations intended exclusively for

(1) This question runs as follows : « Organization of the receiving and the delivering stations, so as to accelerate their business. — Arrangement of the building and tracks so as to simplify shunting (switching) operations and handling, particularly as regards goods in bulk. Mechanical appliances. »

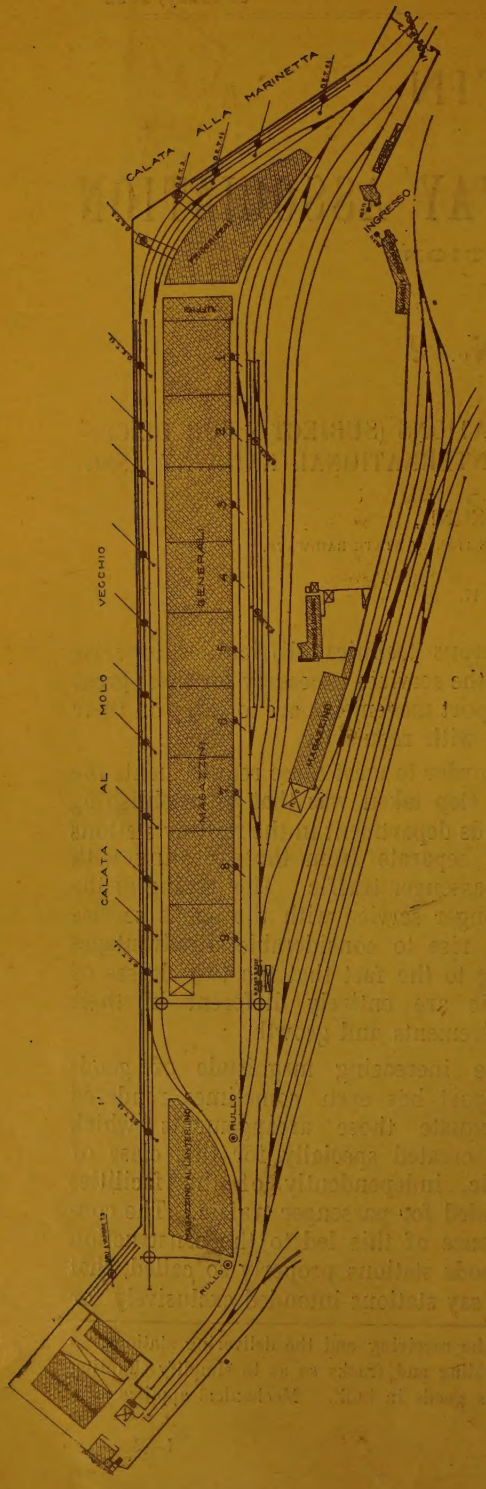


Fig. 1. — Genoa harbour yard, Molo Vecchio. — General arrangement.

Explanation of Italian terms: Ingresso = Entrance. — Guardie doganali = Customs. — Latrina = Latrines. — Officine e alboggio = Lodging house for workmen. — Magazzino War house. — Rullo = Dummy capstan. — Lanternino = Lamp room. — Magazzino al lanterrino = Lamp store. — Officine Marconi = Wireless. — Officine Genovesi = Genoa workshop. — Magazzini generali = General stores. — Calata al Molo Vecchio = Road to Molo Vecchio. — Calata alla Marinetta = Road to Marinetta. — Uffici = Offices. — Frigoriferi = Cold storage. — Gru a vapore 3 T. = Three-ton steam crane. — B. P. 30 T. = Double platform (30 ton) weighbridge. — G. E. T. = Electric travelling crane.

goods traffic and without any facilities for passenger traffic.

Those Italian Railways that are worked by private companies have at present no goods stations properly so called.

The Santhia-Biella Railway Company, with a length of 30 kilometres (18.6 miles), connecting the main Turin-Milan-line to Biella station, has to carry out in this latter station the goods traffic of an industrial centre of the first magnitude. But the woollen and textile industries that are concentrated in the town of Biella are largely served by sidings : the station in itself has only limited facilities. Extensions are, however, being proposed by the Company working the line.

The Italian State Railways have made considerable increase in the provision of the goods stations. In particular they have made :

Harbour goods yards such as that of Genoa-Malo Vecchio (fig. 1) used for forwarding goods from abroad and receiving goods for embarkation;

Transit yards such as the International yard at Domodossola (fig. 3);

Local yards for the serving of a great industrial centre, a great commercial centre, a large grain market, or a large centre of population, etc. Examples of these yards are, Milan-Farini (fig. 4), Milan-Porta Vittoria (fig. 9), Rome-San Lorenzo (fig. 10) and Turin-Smistamento (fig.11).

Lay-outs.

Each goods yard, according to its special class of traffic, should be fitted with arrangements enabling it to deal with inwards and outwards traffic regularly and speedily.

The lay-out of the goods yard involves generally groups or fans of sidings for inward and outward traffic, shunting

Fig. 2. — Genoa harbour yard, Molo-Vecchio. — Warehouses and mechanical appliances.

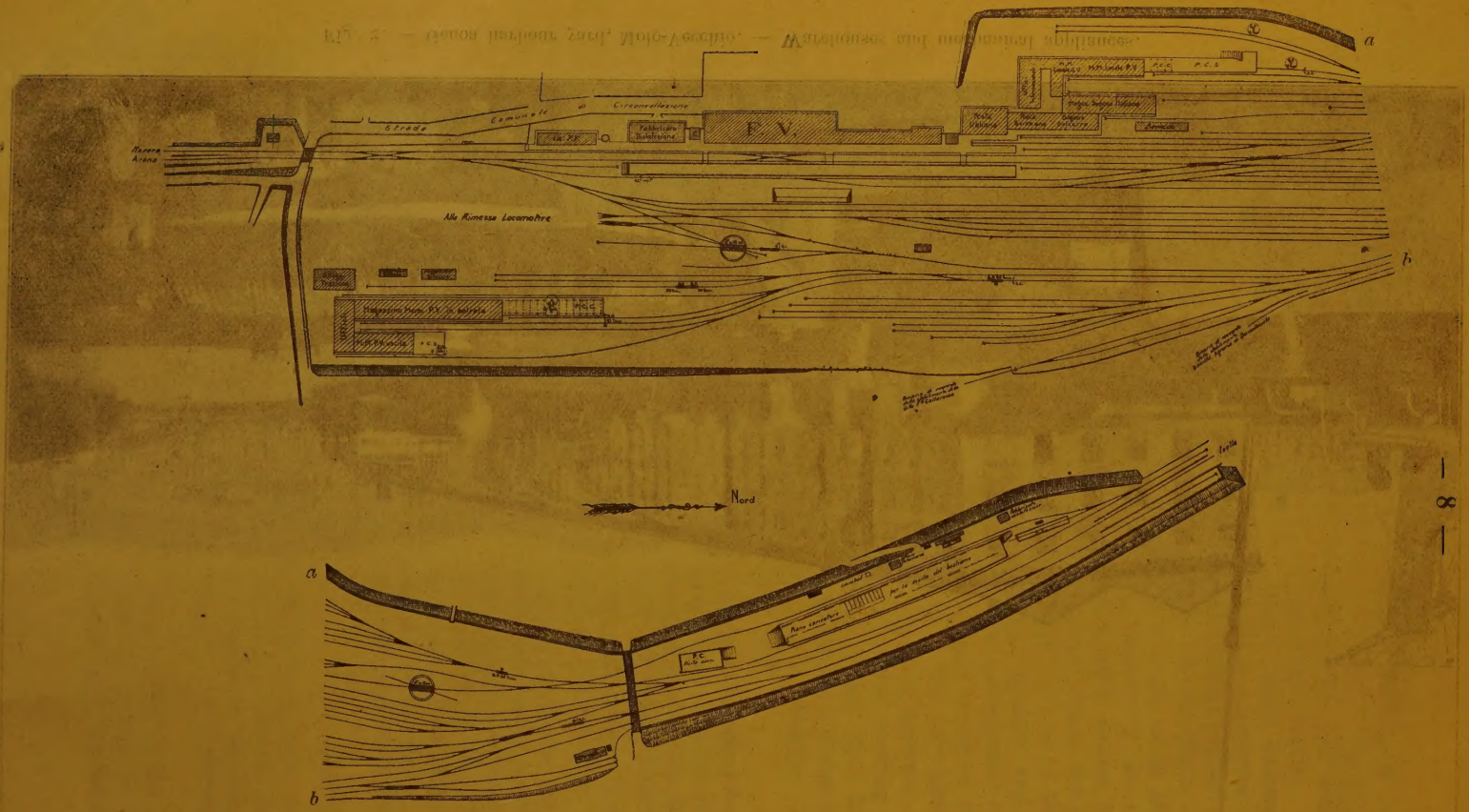


Fig. 3. — Domodossola. — International yard. — General arrangement.

Explanation of Italian terms : Strade comunale di circonvolutione = Public (ring) road. — Alla Rimessa Locomotive = Locomotive Shed. — Allogi Trazione = Lodging house for drivers and firemen.— Fabbricato Disinfezione = Quarantine. — Posta Italiana = Italian post office. — Posta Svizzera = Swiss post office. — Dogana Svizzera = Swiss customs. — Magaz. Dogana Italiana = Italian customs bond. — Uffici Internazionali = International offices. — M. M. Locale G. V. = Fast-goods warehouse. — M. M. Locale P. V. = Slow-goods warehouse. — Baracca = Quarters. Magazzino Merci P. V. in entrata = Slow-goods arrival warehouse. — M. M. P. V. Uscita = Slow-goods departure warehouse. — Uffici = Office. Binario di raccordo dello stabilimento della Ditta F^lli Gattarossa = Private sidings leading to the works of. — Nord = North. — P. C. Visita suini Loading platform for inspection of pigs. — Cabina Trasf. = Transformer cabin. - Ufficio veterinario = Surgeon's Office. Piano caricatore per la visita del bestiame = Loading platform for cattle inspection.

sidings, warehouses, docks and yards and public sidings.

The arrival and departure sidings should be connected to the main line by at least two independent tracks allotted to arrival and departure.

The public sidings are usually connected to the shunting sidings; sometimes they are connected direct to the arrival and departure sidings.

The loading and unloading tracks should be separate and independent of each other, and should also have as many connexions as possible with the shunting sidings or with the arrival and departure sidings.

Actually it is essential that the lay-out in the goods yard should allow the wagons of arriving trains to be rapidly transferred to the unloading tracks and also that the wagons drawn out from the loading tracks may be placed rapidly on the roads allocated to making up the departure trains.

It is also of great importance that the making up of the trains should be carried out regularly in a definite order according to a fixed programme.

The operations of transferring the wagons to the public sidings as well as withdrawing them from these, and the shunting operations for the regular making up of the trains, should be reduced and simplified as far as possible. Hence the necessity for providing special tracks for loading and unloading, connected by several tracks to the shunting sidings or to the arrival and departure sidings.

In general it is necessary that the wagons should be sorted and shunted before they are put on the unloading sidings; it follows that it is desirable that the shunting sidings should be arranged between the public sidings and the arrival and departure sidings.

A characteristic example of this arrangement occurs in the Milan-Porta Vittoria yard (fig. 9) recently constructed and specially arranged for fast goods and for dealing with perishable goods for the market of this great city.

In some cases the shunting sidings, instead of being arranged near the public sidings, are placed on the other side of the yard. An example of this arrangement is to be found in the Milan-Farini yard (fig. 4).

In other cases again, in which special local conditions prevent a large extension of the lay-out, the shunting sidings are arranged in separate yards from the goods yard and even at a considerable distance from it.

This is the case, for example, in the harbour yard of Genoa-Molo Vecchio (fig. 1) which depends for the making up and breaking up of the trains on the shunting yards of Campasso, Sampierdarena and Novi-San Bovo; the first two yards are in the neighbourhood of the harbour whereas the last is at a distance of about 60 kilometres (37 miles).

* * *

After provision has been made for bringing the wagons, to be loaded and unloaded, as rapidly as possible alongside the docks or platforms, care must be taken that the arrangements allow the operations of loading and unloading to be performed with the greatest speed and regularity.

In this respect a distinction must be drawn between the necessary arrangements for goods coming on private vehicles to be stored in warehouses or in the yards and the requirements for transport of goods going direct from public vehicles on to goods wagons or *vice versa*.

The goods generally held up are small

packages or cases of considerable weight and dimensions.

For these goods the warehouses and yards should be laid out in accordance with the latest practice so that the best class of goods may be dealt with in such a manner as to minimise delay, and so that their removal or loading can be done easily and rapidly.

In the better organized goods stations, separate warehouses are arranged for arrivals and despatches.

In the departure warehouses moreover, the goods are sorted out according to destination.

The arrival sheds are sub-divided according to the nature of the goods, *viz.*, valuable goods, perishable goods, goods in small consignments, goods that can remain uncovered, etc.). Sub-divisions are also made for goods to be despatched to destination and for goods delivered from the yard, for arrivals left on hand owing to delay in removal, or refused acceptance, for goods sent in excess of order, etc.

The warehouses and docks are ordinarily served by lateral tracks; sometimes the docks are also served from the ends of the tracks. The tracks in some installations are arranged on both sides (figs. 1 to 3) in other cases on one side only (figs. 4, 9, 10 and 11) so as to give greater ease for access by horse vehicles and hand-carts at the other side of the wagon.

The warehouses on the Italian State Railways are generally arranged laterally with respect to the tracks, as are the Genoa warehouses (fig. 1) and those of Domodossola (fig. 3). Or the warehouses are arranged step-wise (redan arrangement) as in the yards of Milan-Porta Vittoria (fig. 9) Milan-Scalo Farini (fig. 4) Rome-San Lorenzo (fig. 10).

At some stations the warehouses have several floors, which are of advantage in the case of goods that have to remain on hand for some time.

The Harbour goods yard of Genoa-Molo Vecchio, for example, has a main warehouse of four floors, covering an area of 9 054 square metres (97 460 square feet) subdivided into nine large stores per storey; that is to say into thirty-six portions (fig. 2). There is also another three-storey warehouse covering 1 500 square metres (16 150 square feet) with two cold-storage plants, used as a temporary store, for frozen meat arriving from abroad and intended for the interior of the country (fig. 1).

The proportions of the warehouses and the arrangement of covered loading docks and of open goods yards cannot be reduced to a single type because the requirements of each yard and the topographical conditions differ.

* * *

Goods unloaded direct from the wagons on to private vehicles or *vice versa* consist generally of consignments sent in wagon loads, either in separate packages, or in bulk.

Explanation of Italian terms of fig. 4 : Triangolo S. Rocco = San Rocco Triangle — R. L. = Locomotive sheds. — S. P. = Weighbridges. — Via Valtellina = Valtellina road. — Officina = Workshop. — Squadre rialzo = Raised square (docks) covered road for carts. — Magazzino merci in arrivo = Goods arrival warehouse. — Magazzino merci in partenza = Goods departure warehouse. — Riparto delle merci nazionali = Delivery of government goods. — Magazzino per la merci infiammabiliti = Inflammable goods warehouse. — Visita doganale dei pacchi = Customs, parcels inspection. — Laboratorio chimica guardie doganali = Chemical laboratory, customs inspector. — Uffici = Offices. — Capannone recovero mater disinfettati = Shed for recovery of disinfectants. — Grue da 20 ton = 20 ton crane. — Custode = Watchman. — Uffici della Dogana = Customs office. — Magazzino e tettoie per le merci ordinarie = Warehouse and covered yard for ordinary goods. — Regia dogana = Royal (Italian) customs. — Milano centrale = Milan central station..

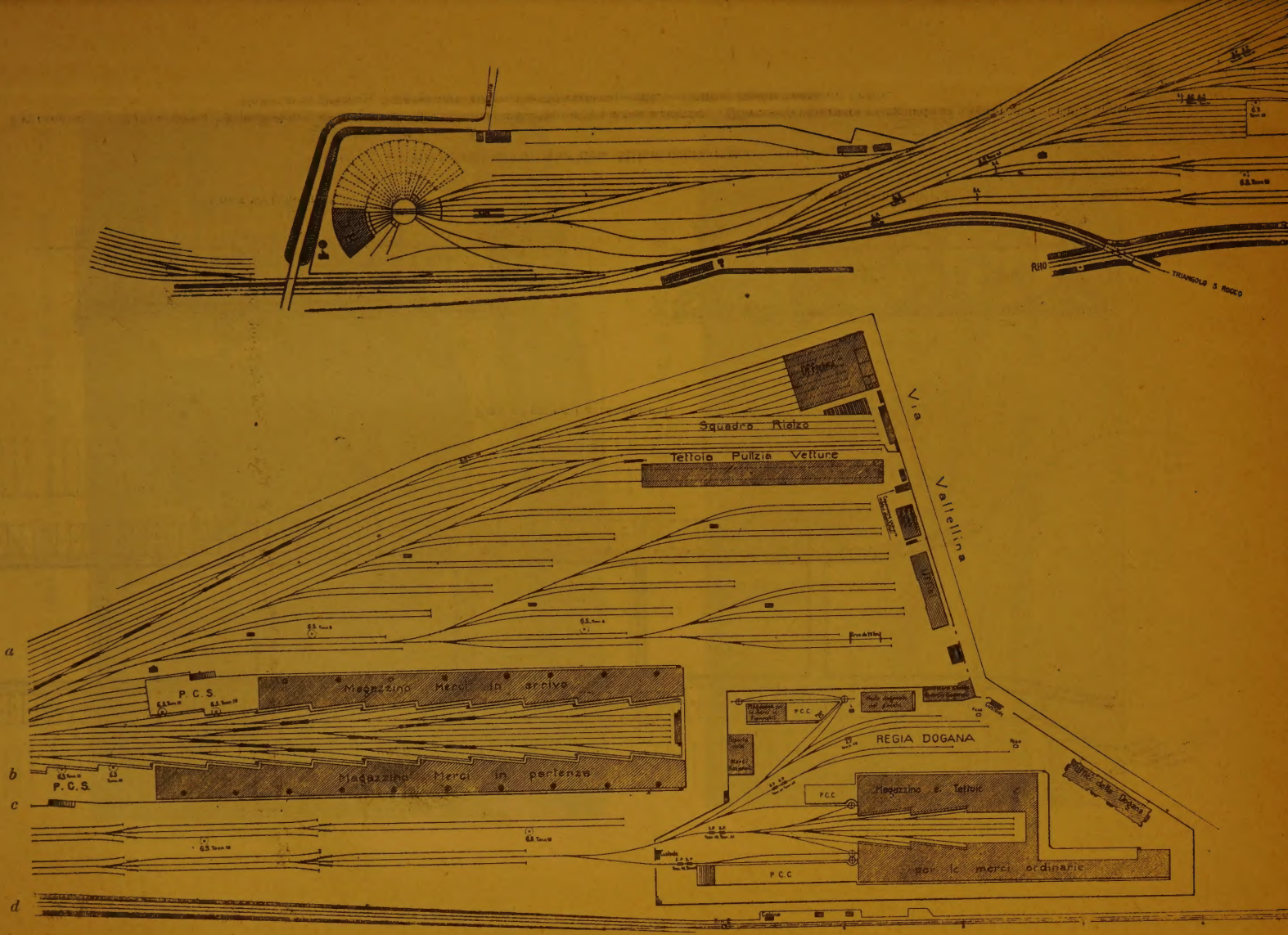
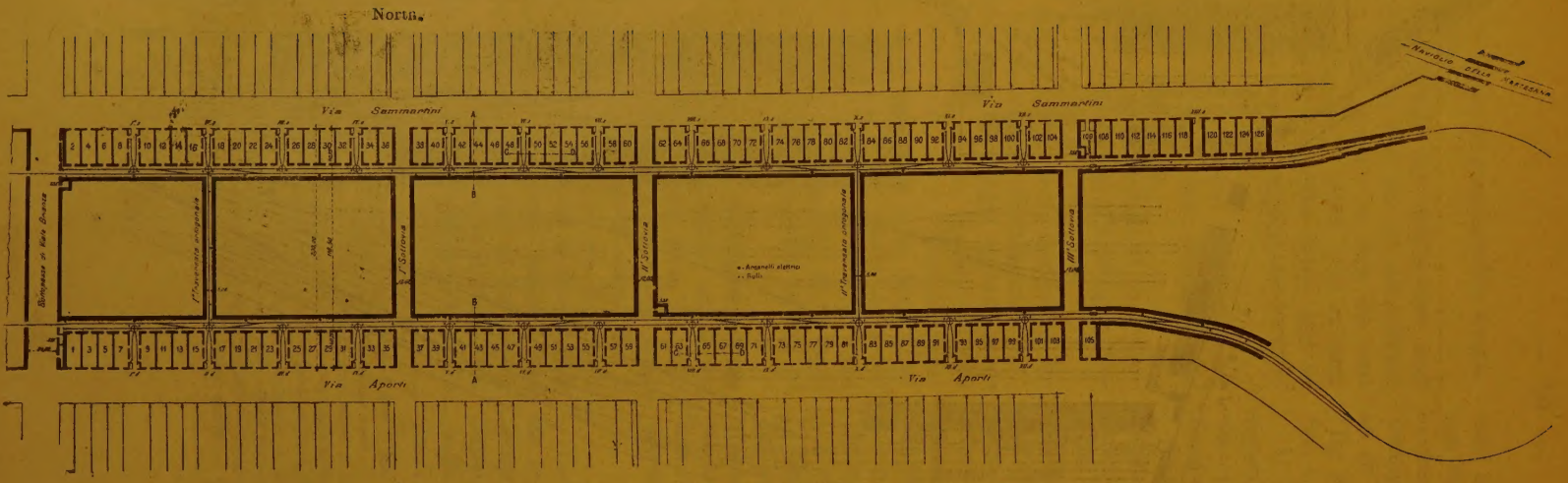
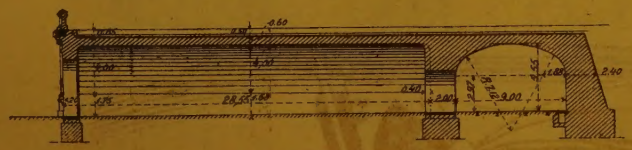


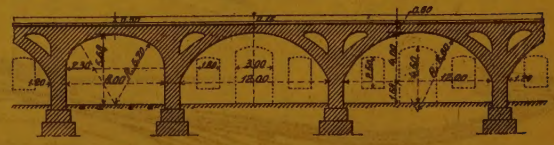
Fig. 4. — Milan goods yard. — Scalo Farini. — General arrangement.



Plan of general arrangement.



Cross section on A-B.



Cross section on C-D.

Fig. 5. — Branch stores of the new Milan central goods yard.

Explanation of Italian terms : Via = Road. — Sottopasso di viale Brianza = Subway for the Brianza Avenue. — Traversata ortogonale = Cross-roads at right angles. Sottovia = Subways. — Arganelli elettrici = Electric capstans. — Rulli = Dummy capstan heads.

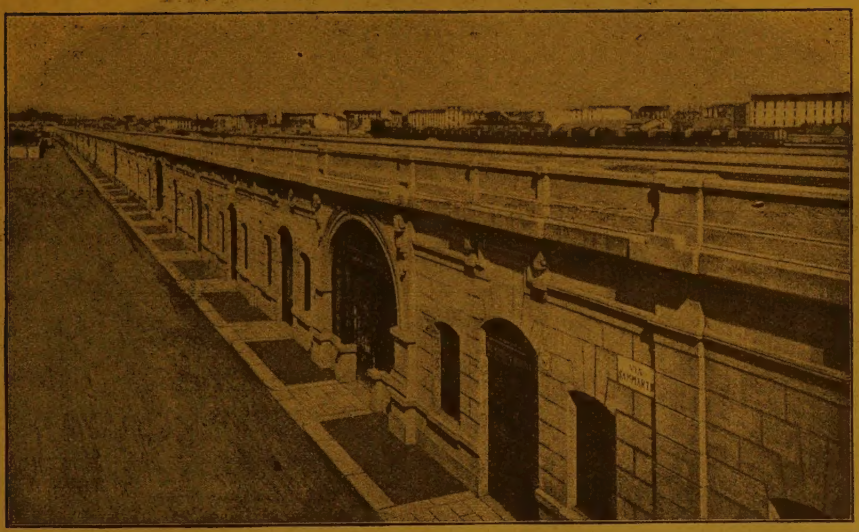


Fig. 6. — Branch stores of the new Milan central goods yard. — Perspective view.

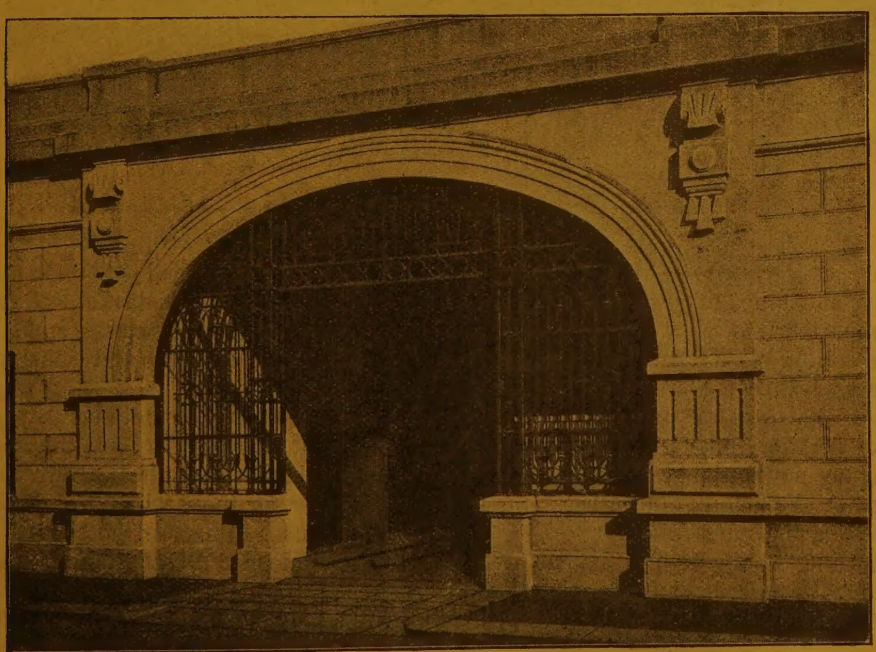


Fig. 7. — Branch stores of the new Milan central goods yard. — Cross road for carts.

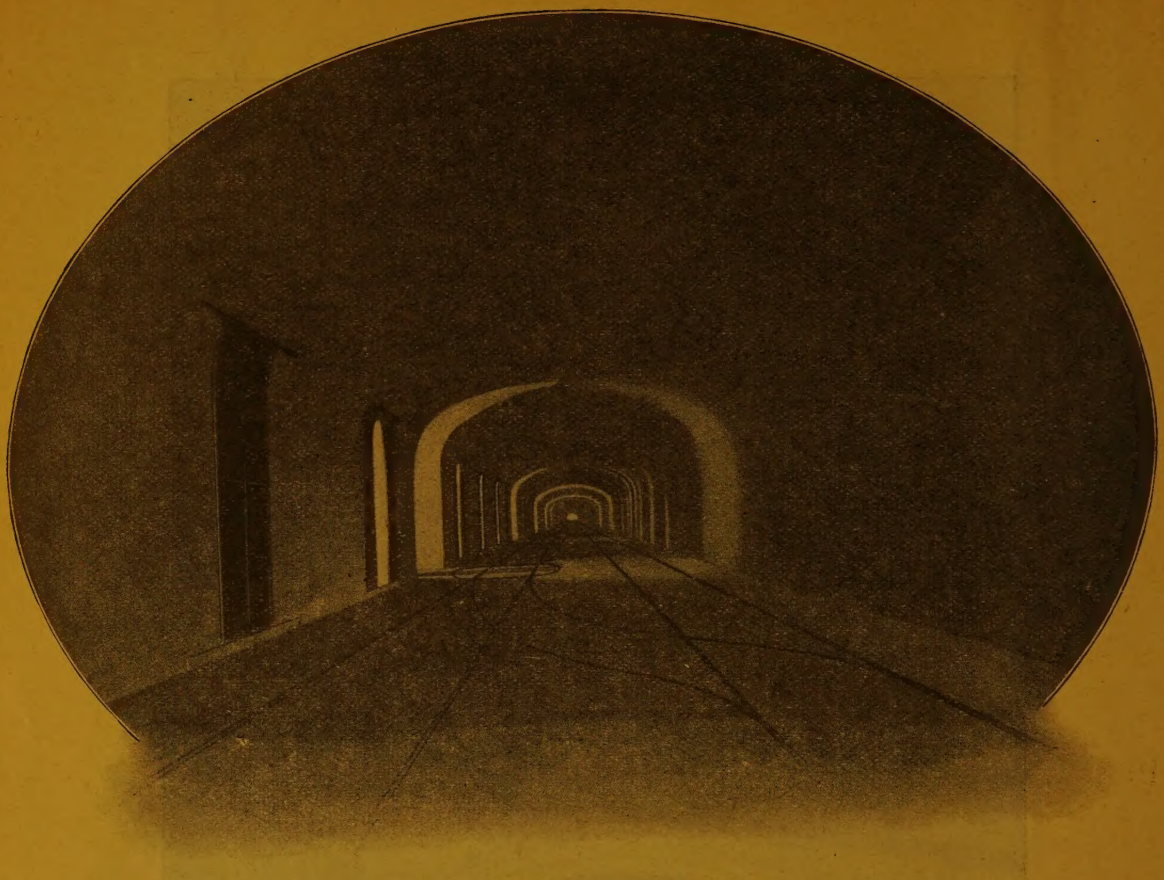


Fig. 8. — Branch stores of the new Milan central goods yards. — Service tunnel.

The arrangement of the tracks for loading and unloading wagons is of special importance to allow of the fullest use of the rolling stock. With this object it is necessary that the arrangement should allow of the disposal of wagons rapidly and of making frequent shunts without having to move too great a number of wagons or disturbing other operations in progress at the same time.

According to the Italian system of tariffs, goods forwarded by wagon loads and coming into the five first classes of the tariff must be unloaded and loaded by the staff of the administration, whereas those of the three last classes must be handled by the senders and consignees respectively.

The requirements of the lay-outs therefore do not vary either for the goods which are handled by the railway administration or for those which are handled by individuals. In fact in both cases the goods are unloaded direct from the wagon to the private cart or *vice versa* and the loading or unloading of the private vehi-

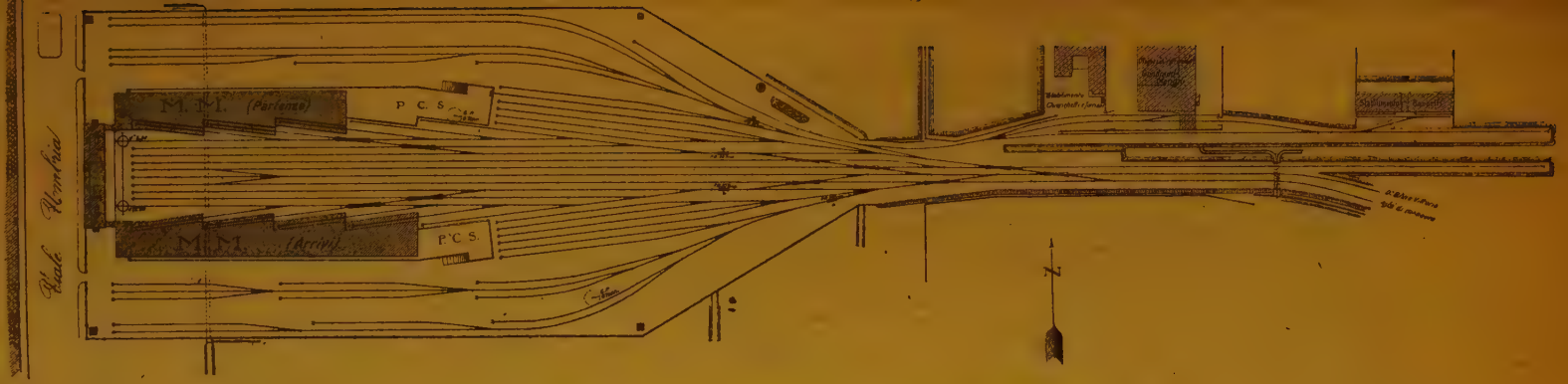


Fig. 9. — Milan, Porta Vittoria, goods yard. — General arrangement.

Fig. 10. — Rome (San Lorenzo) goods yard. General arrangement.

Reference { A = Locomotive Shed (16).
B = — — (38).

Explanation of Italian and French terms : Viale Umbria = Umbrian avenue. — M. M. (Partenze) = Goods warehouse (departure) — M. M. (Arrivi) = Goods warehouse (arrival). Stabilimento = Works. — Magazzini refrigeranti = Cold storage. — D^a Bivio Vittoria = Vittoria branch line. — Asta di manovra = Main siding (to shunting sidings). Avenue donnant accès aux quais = Road leading to the platforms. — Arrivée = Arrival. — Départ = Departure. — Inflammables = Inflammables. — Rampe découverte = Open slope. — Douane = Customs. — Charbon = Coal. — Ateliers = Workshops. — Service du mouvement = Traffic Superintendent. — Bureaux et habitations de service = Office and quarters for the staff.

cles is always and entirely at the expense of the consignee or the sender.

On the Italian State Railways the sidings for loading and unloading of wagons are sometimes arranged in groups, that is to say in an arrangement of parallel tracks connected to each other at one or both ends; or the tracks are arranged in fan-shape, that is to say they are branched from a single track in several divergent lines; or again the tracks may be arranged as longitudinal spurs, that is to say in sections of short length successively connected on both sides or on one side of a main siding only.

* * *

The best type of warehouse and of dock to be adopted cannot be decided from general considerations, nor is it possible to determine the best and most practical arrangement of loading and unloading sidings; these depend on special circumstances according to the kind of work at the different stations.

Thus the lateral arrangement of warehouses placed along the tracks is more practical and preferable to the redan arrangement when it is not necessary to make frequent changes of rolling stock.

In the case of loading and unloading sidings the arrangement in a group of long sidings is more useful when the operations of loading or unloading are carried out on independent tracks so that frequent shunting operations are not required.

An example of these conditions is to be found in the Smistamento goods yard at Turin (fig. 11) specially used for the reception of full wagon-loads. The arrangement of these extended tracks has enabled a length to be obtained, available for unloading, of at least 2 970 metres (9 745 feet) which has rendered it possible to deal with the greatest number of arrivals by placing complete trains of loaded wagons on the long tracks. They can be left there for the whole time required for unloading without frequent changes.

The same advantages occur in the forwarding of goods because the arrangement of the yard enables trains of empty trucks being placed on the long tracks and there left until the loading of the train has been completed.

During the war a large number of Fiat lorries were loaded at this station as well as large quantities of war material for the allied armies.

In 1918 the number of lorries loaded at the Smistamento yard in Turin reached 14 879.

* * *

The service of a goods yard may be considerably expedited by the use of handling appliances such as traversers, capstans, belt conveyors, shoots, suction apparatus, goods-lifts, wagon-lifts, etc.

At the stations on the Italian railways there have not been many applications of these methods. It should be stated, however, in this respect that, in the yards of the Italian railway system, the goods received and forwarded are so varied as not to lend themselves to the use of any special appliance.

On the other hand in the harbours destined to receive goods in bulk and in large quantities frequent use is made of electric lifts, pontoons, overhead cranes, fixed and movable cranes of various radii, etc. Similar plant is frequently used in works having sidings where mechanical appliances are specially adapted for the work done in the said industries.

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Private sidings considerably increase the capacity of a good yard and also have

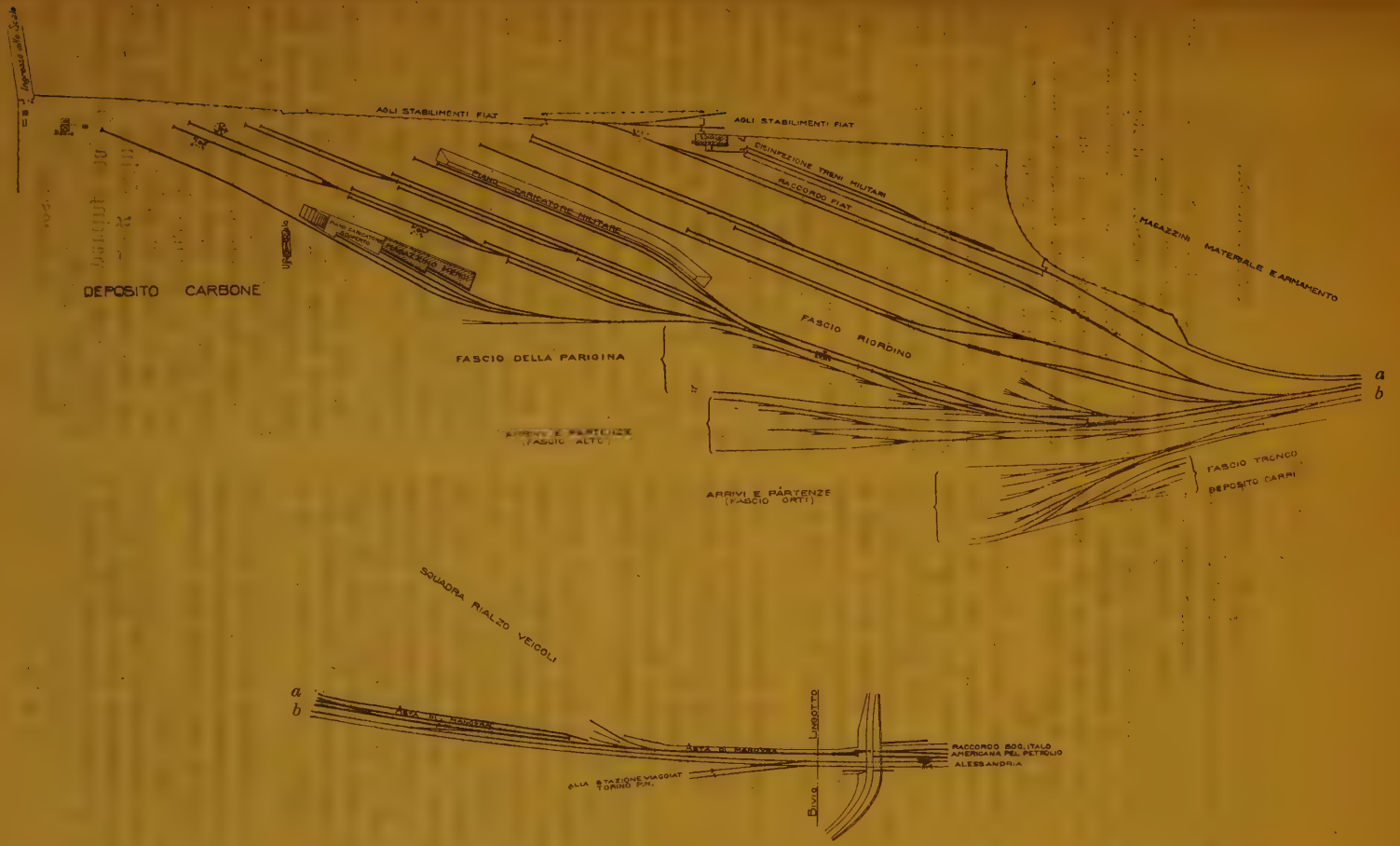

Fig. 11. — Turin-Smistamento goods yard. — General arrangement. — Plan.

Explanation of Italian terms : Ingresso allo scalo = Entrance to the yard. — Agli stabilimenti Fiat = To the Fiat works. — Disinfezione treni militari = Disinfection of military trains. — Raccordo Fiat = Fiat sidings. — Magazzini materiale e armamento = Rolling stock and permanent way stores. — Piano caricatore militare = Military platform. — Fascio riordino = Making-up sidings. — Piano caricatore scoperto = Open platform. — Magazzino merci = Goods warehouse. — Deposito carbone = Coal depot. — Dazio Toll-house. — Fascio della Parigina = Paris sidings. — Arrivi e partenze (fascio alto) = Arrival and departure sidings (upper). — Arrivi e partenze (fascio orti) = Arrival and departure sidings (east). — Fascio tronco deposito carri = Main siding to standing sidings. — Squadra rialzo veicoli = Raised square for carts. — Asta di manovra = Main shunting siding. — Alla stazione viaggiat. Torino P. N. = To Turin P. N. passenger station. — Raccordo Soc. Italo-Americana pel petrolio = Italian-American Petroleum Company's Sidings.

the advantage of simplifying the operations and lessening the responsibility and expense of the railway administration.

The provision of these sidings has, moreover, the additional advantage of reducing the cost of transport between the goods yard and the works on the siding and of avoiding double loading and unloading of the goods.

Italian legislation favours the construction of private sidings. Act No. 272, dated 30 June, 1906, has brought these sidings under the same head as light railways and these installations may be claimed to be of public utility and to benefit by the provisions that have been made for expropriation under such conditions.

The Italian State Railways for their part encourage the installation of private sidings by supplying the material for the permanent way and the necessary labour for the construction of the track, and they also facilitate the working of these sidings as far as possible.

The new central station at Milan (Nuova Centrale) is a special example of warehouses with branch sidings (figs. 5 to 8).

The station is raised 7 m. 50 (24 ft. 7 in.) above the level of the ground and the ground floor under the brickwork viaduct on which the station is built has been used for the formation of 116 warehouses, each having an area of about 350 square metres (3 770 square feet) and a height of about 6 metres (19 ft. 8 in).

These warehouses are served by tracks arranged in service tunnels and connected by inclines to the arrival and departure sidings of the yard.

These warehouses are leased to a limited company known as the « *Milan Central Station Warehouse Company Limited* ».

* * *

Organization.

Proper organization is, of course, indispensable for the best output from goods yards. For this reason good lay-out and good organization are interchangeable terms depending on each other for the satisfactory working of goods yards.

To obtain a regular goods service, it is above all necessary to adopt specialization in the yards. This, of course, is not either possible or necessary except in the case of large commercial, industrial and populous centres.

The lay-out of goods yards is generally decided by the class of goods to be dealt with. Thus, for example, the Smistamento yard in Turin (fig. 11) built last year at the outskirts of the city, is reserved exclusively for arrival and departure of slow goods. Fast goods traffic is accepted on arrival only and in full-wagon loads; live stock traffic is excluded.

These restricted arrangements have only been adopted in order that the Smistamento goods yard in Turin may be able to meet the conditions for which it was provided, that is to say, to reduce the congestion in the other yards situated inside the city, and to relieve them of a portion of the goods in full-wagon loads particularly of low value goods sent in bulk.

On the other hand the Porta Vittoria yard in Milan (fig. 9) which is near the large markets of the City is reserved for the arrival and departure of fast goods.

When the classes of goods that the yard must deal with have been settled it is necessary to arrange for the lay-out of the warehouses, in order that the docks and the discharging sidings for goods arriving and departing may be separate from other goods.

Finally it is necessary to adopt the

simplest, surest and quickest methods so that goods may be loaded and despatched with regularity or received and distributed without delay.

* * *

In the case of outward goods it is important to have a good method for accepting and loading them quickly.

In well organized yards the accepting of the goods is never entrusted entirely to the control of the officials at the warehouses and docks. The acceptance of the goods to be forwarded really involves a careful checking of the packages, a minute examination of the consignment notes, a thorough knowledge of the routes, of traffic en route, of special arrangements in sorting yards, etc. Hence the necessity for placing the acceptance under the responsibility of the chief clerks or stationmasters who by their greater knowledge and superior position are better able to ensure that the best working of the traffic will ensue.

In the organization of the service for the acceptance of small consignments a system has been tried with advantage in which special notice boards, kept for the purpose inside the warehouses, show the destinations to which the trains will run or the routes that they will follow.

In order to properly regulate the acceptance of full wagon loads, empties for such loading should be distributed over different sidings in the yard according to their destination, and thus reduce the amount of shunting required for making up trains in the order desired.

To be effective all shunting operations should be carefully overlooked, and small special locomotives should be used for this purpose. The shunting operations should be carried out at least twice a day at times previously fixed to suit the general working of the yard.

By such arrangements the Italian State Railways have managed to reduce the time between acceptance and departure of slow goods traffic to an average of twelve hours.

* * *

With regard to arrivals it is particularly important to ensure that goods are rapidly placed at the disposal of the consignee and that they are unloaded quickly. It is therefore necessary that the advice note sent to the consignee advising him of the arrival of the goods and requiring him to remove them and so avoid delay in accepting delivery, should be sent at the same time or before the wagon has been put in place for unloading.

Rapid despatch of the advice note of arrival and prompt removal of the goods are particularly important in the case of consignments sent by full-wagon load, because in this case goods remaining at owner's risk involve the standing idle of the wagon in the unloading sidings.

In the case of goods sent in small consignments unloading is carried out by the Administration in such manner as to prevent the holding up of wagons and blocking of the tracks, by placing the goods in the warehouses or delivering them through cartage contractors direct to the premises of the consignees.

In order to obtain more rapid delivery of the advice notes the Italian State Railways have drawn up special forms so that small consignments can be unloaded and checked in the warehouses, whilst the invoices are made out and sent from the offices.

The sending of the advice notes to consignees in large towns is performed by

messengers, each allotted a definite area of the town and travelling by tramway or bicycle. The Italian State Railways have recently stated on the tariffs that the consignees of goods sent by full-wagon load may be advised also by express letter or by telephone or even by telegram when they so desire at their own cost.

In the more important stations a system is in force by which the consignees apply direct to the yards for their advice notes at least twice a day : once in the morning and once in the afternoon. According to the conditions of the traffic this method of obtaining the letters is considered as equivalent to their delivery at the premises of the consignee.

Finally in some yards boxes are arranged in which the advice notes are deposited under the names of those consignees who are constantly receiving goods at this station and who themselves undertake to collect the advice notes.

* * *

Make-up of trains.

If the proper make-up of trains is well thought out beforehand it may complete the advantages of the good lay-out and organization of a goods yard. It will materially assist in speeding up loading especially of goods sent by full wagon load.

With a view to accelerating the loading of wagons by the public the Italian State Railways have adopted the system of asking for a deposit from the sender at the time when he applies for a wagon; the deposited amount is retained by the Administration either if the sender cancels his order or fails to load within the required period.

The only exception to this rule is at large centres with ordinary wagons when a sufficient supply of these is available, — especially during the vintage season when the railway Administration puts rolling stock at the disposal of the public for the carriage of grapes or unfermented grape-juice, — to meet all demands.

The Italian State Railways also exempt some industrial concerns or commercial houses from paying deposits; the required amount however must be paid to the Administration if the consignor fails to load within the stipulated period. This concession cannot, however, be considered as an exception to the general rule because it depends entirely on practical considerations. These firms are under contract to the Administration affording guarantees apart from the deposits, and, under these conditions, it is desirable to avoid superfluous accountant's work.

With a view to ensuring more rapid loading of the wagons the Italian Railways have also temporarily adopted a system of deposits by the consignor of a supplementary amount which is retained by the Administration when the sender, after having received a wagon, delays the loading.

* * *

The infliction of warehouse dues and demurrage charges acts as an incentive on the part of the public for the quicker unloading of goods on arrival.

The Italian Railway tariff fixes the charges for warehousing at a higher rate for goods included in the first five classes of traffic and at lower rates for those of the last three. This measure was taken because delay in removing the goods increases the responsibility of the Administration for care thereof, and the risk rises according to the value of the same.

In the case of goods coming under the three last classes which are delivered by full-wagon load and of which the con-

signee is required to unload himself, the traffic rate settles the charge for wharfage per wagon per day. The total of the rates for wharfage must be paid to the Administration when it is higher than the total of the rates for warehousing the contents would be.

During periods of heavy traffic or when the amount of goods arriving at any particular station becomes so great as to cause inconvenience in that station, the Italian law gives power to the Administration to reduce, up to a maximum of one third of the time, the period for removing the goods, and to increase temporarily by one third, the rates for warehousing and for demurrage wharfage.

Moreover, wheraas a small delay might be allowed a long delay disorganizes service of the yards, thus it has been settled as an exceptional arrangement that rates for warehousing and for demurrage are increased five-fold after the first two days of delay.

Finally, in order to prevent goods holding wagons up owing to their not being unloaded, it has been temporarily authorized that the railway itself may unload the goods at the expense, risk, and peril of consignees without obligation on the part of the Administration to place them under cover and to take care of them. At the same time, in order to avoid not only the wagons standing under load, but failure to remove the goods, the period after which the Administration has the right to sell the goods has been reduced from six months to three months.

* * *

The preceding considerations with regard to the traffic arrangement to improve the working of the goods yards, apply equally to the accessory services of the yards.

In order to prevent the detention of wagons the Administration may allow owners of private sidings to unload goods in the station yards. In cases where such work is done, station, instead of siding dues, are charged if any detention of the wagons takes place in the yard or they are not withdrawn to the private sidings.

Another interesting case is that of the consignees who, with the object of reducing the amount of demurrage ask that the weight shall be checked on arrival. To avoid this difficulty it has been settled that the demurrage shall remain in force for the whole time that the goods, on the request of the consignee, remain in the yard before weighing and during weighing, unless the check weighing should show a loss for which the railway is responsible.

* * *

We shall limit ourselves here to stating in principle, the arrangements which decide traffic questions on the Italian Railways. This is not the time to go into detail, because the arrangements which are now in force are largely temporary in character and arise from the fact that they have been adopted in order to meet great difficulties which, in consequence of the war, have arisen in railway working.

When the services of the railways, and also the life of Nations in general resume their normal course arrangement of details in this respect will require to be revised, modified and even partially abolished.

* * *

Bonuses to the staff.

With the object of obtaining quick and profitable use of the rolling stock and

speeding-up transport, the Italian Railways have arranged special bonuses for employees who by hard work, and interest contribute in obtaining this object.

These bonuses are allotted as a permanent arrangement in the cases and within the limits that follow :

First bonus. — Allotted to a certain number of employees in the Central Offices who are entirely responsible for wagon distribution.

Second bonus. — Allotted to the employees in yards and on trains for prompt and regular loading of small consignments in wagons on pick-up trains, and also for the sorting of the goods during the running of trains or in specified yards.

This sorting consists in getting together by transhipment from wagon to wagon, goods destined for a single yard or for several yards situated on the same route, in such manner as to avoid, as far as possible, unnecessary transhipments and thus obtain more rapid delivery of these small consignments on reaching destination.

Third bonus. — Allotted to employees in yards and to the tranship gangs travelling on certain pick-up trains for the regular making up of extra wagons for small consignments and getting them promptly away.

The object of this bonus is to interest the goods-yard staff that handles large quantities of small consigments, and also to the staffs of shunting yards that have a heavy traffic for different destinations, to effect the sorting and grouping of the goods in such a manner as to make up through wagons.

These wagons should contain goods for the most distant yards possible in such manner that they can run over the latter portion of the journey, or the greater portion of the whole distance, in through trains.

Fourth bonus. — Allotted to the yards which regularly make up trains of certain definite goods in such manner as to simplify and reduce the breaking up and remaking of the trains, and thus accelerate the movement of the stock and reduce the time in transit taken by full-wagon loads.

Fifth bonus. — Allotted to the staff of the more important harbour and terminal shunting yards for quickening up the work of forwarding and arranging the routes of the wagons loaded in the ports without interfering with the work of loading at the port itself.

* * *

On the Italian State Railways there are, finally, temporary bonuses usually allotted to the staff in autumn and in winter when the traffic is heavy, and the weather conditions unfavourable to the running of trains.

These bonuses, which have the object of increasing the mileage run by rolling stock and avoiding train delays, are generally fixed in the following manner :

Bonus « A ». — For every wagon arriving loaded or empty in a yard and sent out empty or reloaded with another train within a maximum of thirty hours from time of arrival.

Bonus « B ». — For every wagon leaving a through yard or siding, provided that during the week the total number of wagons leaving the same yard is not less than the number of wagons arriving. This bonus is given to maintain equality between the number of wagons arriving and leaving and to avoid congestion on some parts of the system.

Bonus « C ». — For each wagon-day of demurrage charged on full-load wagons. This bonus forms an efficient stimulus to the staff to hasten the despatch of advice notes to the consignees and also hastens shunting of the wagons and getting them into position for unloading.

The regular receipt of the demurrage charges is also better ensured by this means.

Conclusions.

From the experience obtained on Italian Railways, relating to the subject with which we have dealt, we think we may draw the following conclusions :

1. — *In the arrangement of the lay-out of goods yards, it is important that the goods service should be entirely distinct from the passenger service.*

2. — *In goods yards special tracks should be reserved for loading and for unloading and they should be well connected by several independent tracks to the shunting sidings or to the arrival and departure sidings.*

3. — *The groups of shunting sidings should be, as far as possible, near the loading and unloading tracks and, whenever possible, situated between the loading and unloading sidings and the arrival and departure sidings.*

4. — *The choice of an arrangement for warehouses, in relation to the tracks, depends on the special conditions and requirements of the various yards; in general an arrangement of warehouses parallel to the tracks or step-wise (redan form) is adopted.*

5. — *Warehouses of several floors and fitted with mechanical appliances are most useful in harbour goods yards, because, at these places, there is usually an accumulation of goods which require to be stored there for some time according to the arrival or the departure of the ships.*

6. — *Several arrangements are adopted for the loading and unloading tracks for wagons. The arrangement of parallel tracks connected together at one or both ends by other tracks is generally considered the best and the arrangement of longitudinal spurs is also good.*

7. — *It is desirable to encourage the extension of private sidings, they increase the output of the yards, are of advantage to trade, simplify the shunting operations and reduce the responsibility and expenditure of the Railway Administrations.*

8. — *The specialization of goods yards is particularly to be recommended in large towns.*

9. — *In organizing the services special care should be taken that the operations for accepting and loading goods should be well regulated, for on this, in a great measure, depends the possibility of obtaining regularity as well as speed in transport.*

10. — *With regard to goods on arrival, the first care must be given to placing the goods at the disposal of the consignee and to sending out the advice notes in order to hasten unloading and delivery as far as possible.*

11. — *Special arrangements of tariffs and of bonuses to the staff may be of great utility in hastening the loading, the unloading, the determination of the route and the delivery of the goods; also in obtaining greater regularity and speed in the service dealing with small consignments of goods, and in the shunting and marshalling of trains.*

[624 .63 & 721 .9]

REPORT No. 7

(Denmark, Norway and Sweden)

ON THE QUESTION OF REINFORCED CONCRETE (SUBJECT IV FOR DISCUSSION AT THE NINTH CONGRESS OF THE INTERNATIONAL RAILWAY ASSOCIATION), (1)

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Figs. 1 to 81, p. 32 to 81.

PART I.

General Observations.

CHAPTER I.

As is generally known the question of the use of concrete and reinforced concrete on railways, was last dealt with at the meeting of the International Railway Congress held in Washington in 1905.

The question of the use of concrete was also raised at the last session of the Congress (Berne 1910) in the first section, question IV (long railway tunnels); but on this occasion the question was not treated exhaustively; moreover, the other applications of concrete were not discussed.

Having been entrusted with the task of presenting a report concerning the use of concrete and reinforced concrete on the railways of the Scandinavian countries we will commence by referring to the discussions that took place at the Congress in Washington in 1905, and recapitulating the main conclusions adopted at this Congress (2).

1° Reinforced concrete has had many and important applications on railways. Both from the technical and economical points of view, it can fully and successfully compete with masonry and timber or steel construction;

2° Tests of reinforced concrete structures, theoretical researches on the question, and the results of practice justify the conclusion that the use of such structures need not cause any apprehension, and that their application can be recommended to railway administrations;

(1) This question runs as follows: « Use of ordinary concrete and of reinforced concrete on railways ».

(2) See *Bulletin of the Railway Congress*, July 1906, p. 1095, and *Proceedings of the seventh session* (Washington, 1905), vol. I, p. IV-287.

3° Railway practice shows that carefully built reinforced concrete structures give excellent results and hardly require any maintenance. For this reason, the use of reinforced concrete should be recommended, even if the cost of construction is occasionally higher than for other systems of construction;

4° Reinforced concrete structures are especially useful in countries where building materials, such as stone and iron, are difficult to obtain in large sizes;

5° Reinforced concrete makes it possible to execute works quickly with materials readily obtainable, and this avoids the necessity of giving special orders to manufacturers, which is often troublesome in practice.

If we consider the nature of these conclusions it cannot be doubted, from the extended use of reinforced concrete structures on railway systems, that they have been approved from almost all points of view and that all that was expected of reinforced concrete and of the importance of this new constructive material has been practically confirmed.

Constructional work in reinforced concrete has succeeded everywhere. Actually reinforced concrete is a constructive material with which no technical man can dispense, and it may be said that there is no other constructional material which has had such rapidly extended use in so short a time.

Allowing this development, an attempt has been made to find a proper basis for the calculations for reinforced concrete construction and to improve the various details of its construction while at the same time finding new fields for its employement. The increase in its use was such that, whereas at the beginning reinforced concrete was chiefly used for buildings, floors and such structures, there is now scarcely any branch of the technical side of constructional work in which reinforced concrete has not found an application and given complete satisfaction.

Reinforced concrete has proved as important in the construction of bridges, roads and hydraulic works, as in that of buildings, and consequently it is quite natural that railways, which include all of these branches should have benefitted particularly by its use.

The following advantages have led to a more and more varied use of concrete in Scandinavia and in other countries :

Its extremely low cost as compared with iron. — In Denmark, in several cases relating to large constructional works, the tenders for inronwork were as much as 50 % higher than the corresponding tenders for structures in reinforced concrete. A great portion of the cost of the latter is incurred in the shuttering, and this is nearly the same in the case of light structures as in that of massive structures; it is consequently in the latter class of structure that the lower cost, as compared with iron, is more pronounced.

The low cost of maintenance compared with the corresponding cost in the case of iron construction work. The economic importance of this feature becomes more and more pronounced, because the deteriorating influence of the atmosphere and particularly that of the smoke from locomotives makes itself felt with time, and the older that iron constructions become the more maintenance they require.

A few years ago in an article in the *Zentralblatt der Bauverwaltung* it was stated that the very low cost of maintenance played so great a part that an iron bridge, for example, would need to be about 15 % less costly as designed in

order that it might be able to compete commercially with reinforced concrete.

The protection offered by it against the destructive effects of fire, in consequence of which concrete is not only superior to iron, but also to almost all other materials of construction.

The massive form of concrete and its monolithic character, which show a great advantage, both in the construction of houses and in other cases. We may quote for example that on concrete railway bridges no appreciable vibration can be felt, if the hand is rested against the bridge at the time that a train is passing over it, whereas on iron bridges considerable vibration is felt in various portions of the structure. In small bridges it is even possible to observe the girders jump on their supports when the train passes over.

The ease with which reinforced concrete can be made to take any shope and adapt itself to all the exigencies of architectural form. This point will be referred to further on; we will content ourselves here with the remark that reinforced concrete may be made to assume artistic forms without the use of sham decorations, as is proved in a large number of structures of reinforced concrete, as for instance in bridges.

It follows from the foregoing that reinforced concrete possesses valuable properties and there is no doubt that conclusions 1, 3 and 4 of 1905 may still be adopted for the Scandinavian countries.

It appears to us however that a different point of view must be taken with regard to conclusions 2 and 5 and we think that it is necessary in particular to make a certain reservation relating to conclusion 2 — in any case with regard to the form in which it is worded.

Experience has proved that reinforced structures, if rationally and carefully constructed, stand perfectly well; but, on the other hand, such structures may also give rise to misgivings, which shows that care should be exercised in the selection of this material.

If one examines a structure of reinforced concrete, it sometimes happens that one does not experience that feeling of safety which one usually feels in the case of an iron structure and this arises from the fact that, in such structures, there are several causes which may introduce faults that cannot exist in the case of iron structures.

A reinforced concrete structure may very often be designed too closely in accordance with theory — and consequently may be badly designed — without regard to the various conditions that exist on the site, and to the manner in wich the work of construction will be carried out. For financial reasons, it is possible that, in the course of construction, economy may have been effected in the thickness of the concrete and particularly in the quantity of iron used in it, so that if the execution of the work has not been exactly in accordance with the drawings an error in the casting of the concrete may have given rise to danger. It has often been noticed, particularly in the case of schemes carried out by contractors and engineers who are not accustomed to practical work, that the iron bars are anchored to the concrete over too short a length or (at the joints in the bars) the overlap is of a length which though perhaps theoretically admissible, is too short in practice. Such features, as the result of imperfect execution of the work on the ground, may, when taken in combination, prove dangerous; the theoretical length necessary for the overlap of two

iron bars is often very short, it may be only 20 to 30 cm. (8 to 12 inches) and consequently the strength of the work may depend on the manner in which the concrete has been filled in over this short overlap.

It may also sometimes be seen that reinforced concrete structures are designed in such a manner that the stopping of the operation of filling in at the wrong time may constitute a source of danger to the whole structure, or in any case may upset the calculations on which it has been based.

The resistance of concrete depends in a high degree on the manner in which the concrete has been mixed and filled in, and it is unpleasant to realize that, as a consequence of want of care, this resistance may easily become reduced to one-half of the resistance to compression used in the calculations, just as the stresses in the iron may very easily be increased much above the calculated value, solely by the bad placing of the iron in the girders.

The strength of a reinforced concrete structure depends, more than any other form of construction, on its proper execution and requires constant and conscientious attention by the workmen as well as by the foreman and engineers, and this is a point which sometimes may give rise to anxiety. Once the filling in has been finished all checking becomes impossible, and it is only later, by the development of cracks or other defects that the mistakes that have been made are discovered. In this respect structures of wood and of iron, for example, are much more accessible for examination at any time.

The causes of the mistakes that occur most frequently on the ground will be mentioned later.

CHAPTER II.

Materials for and preparation of the concrete.

It is known that the strength of concrete may vary by more than 100 % according to whether the materials of which it is composed are suitable or not.

The strength of concrete varies greatly according to whether the stones are large or small, according to whether the aggregate is coarse or fine, clean or dirty, and there is often a difference according to the brand of cement used.

In particular the *size of the aggregate* is of great importance; according to experiments made on the Danish State Railways, it has been found, for example, that 1:3 gravel concrete (that is 1 part of cement to 3 parts of gravel) gave the following resistance to crushing after 28 days.

	Kgr. per cm².
Coarse gravel	464
Relatively fine gravel	233
Mixture of fine and coarse gravel (half and half)	328

If, in a large structure of iron it has been ascertained by the results obtained from test-pieces, that the iron used is of good quality, it may be taken for granted that the whole of the ironwork delivered is of the same quality. But such is not the case with materials such as gravel and stones, which are not, as in the case of iron, of constant and uniform quality. After the construction of the new railway station at Copenhagen, where in the years 1907 to 1910 about 300 000 m³ (392 000 cubic yards) of gravel were delivered which were used in greater part for mixing in concrete, there was opportunity to observe the difficulties arising from this source. In the sand-pits from which

the gravel is obtained coarse gravel of good quality, is often found side by side with fine sand which cannot be used, and it is difficult to make sure that some bad material is not mixed with the good gravel (particularly in the case of large deliveries); and if, by chance, material of inferior quality is used in a place in which the concrete is exposed to the maximum of compressive stress, or at a point where two iron bars are connected by concrete the situation may become dangerous. In such a case the factor of safety may easily be reduced by one-half.

The cement is much the most uniform and dependable of the constituents that go to make up concrete, but even with this one may experience unexpected difficulties.

It is not uncommon at the moment when the cement is being used on the ground, for it to prove of inferior quality to that which the works samples had led one to believe; this may, for example, arise from such circumstances as careless treatment in transport, bad conditions of storage or other similar causes. If exposed to moisture cement easily becomes « stony »; it may change in character by being stored a long time, in such manner that instead of setting slowly it sets rapidly, wich as is well known, may have very serious consequences, particularly for structural work in reinforced concrete. It has also been found that cement has been made so impure by the packing that it has become quite useless, A particularly striking example occured at Copenhagen a few years ago, when a very large structure of reinforced concrete was being constructed; on taking down the shuttering of some fairly heavy columns (cross-section 60 by 120 cm.) (24 by 48 inches) it was seen that concrete of a 1:2:3 mixture and already six weeks old, had not set at all, but was damp and non-cohesive as if it had been just filled in. Chemical tests of the concrete showed that the cement contained a few parts of sugar per thousand, introduced by the material it had been loaded in and that this minute percentage of sugar had caused complete destruction of the cement and consequently of the concrete.

It is therefore absolutely necessary to ascertain the quality of the cement before it is actually used and this is always done on the Danish State Railways. During the period that the cement is being used on the ground, it is desirable that, simple tests should be made from day to day. This can easily be done by mixing a handful of cement with water and moulding it on a sheet of glass, a plate or other surface; by pricking it from time to time, it can be seen whether the cement has the desired rate of setting (and in any case whether it sets) and by keeping the set cement for two or three days under water it can be ascertained whether it is sound or not.

In Denmark this simple test is often made on the spot.

Mixing of the concrete. — Apart from the quality of the materials, the strength of concrete depends largely upon the care with which the concrete has been prepared and filled in. It is constantly found that if samples are taken of cement, gravel and stones on the spot, and they are sent for test to the Laboratory (*Materialproveanstallen*) with the request that concrete cubes be made from them and tested, these cubes are always found to have a strength about double that obtained from cubes made with concrete mixed on the site — although in both cases the materials are the same. From the check-tests made by the Danish State

Railways it has been found in many cases that, if the resistance to crushing after 28 days, for concrete of 1:3:4 mixture is about 180 to 200 kgr. per cm² (2 560 to 2 845 lb. per square inch), in the case of cubes made at the Laboratory, it only amounts to from 100 to 110 kgr. per cm² (1 422 to 1 565 lb. per square inch) and sometimes even less for cubes cast on the site.

This large difference of strength — notwithstanding the checking carried out on the ground — arises from :

a) bad mixing of the different constituents of the concrete;

b) Want of ramming of the concrete and finally;

c) Excessive addition of water.

This last point, in particular, is of great importance as will be seen by the series of tests given below on the resistance to crushing of 1 : 3 concrete with different admixtures of water :

1 : 3 concrete.	After 7 days.	After 28 days.	After 3 months.	After 6 months.
	Kgr. per cm².			
10 °/₀ of water .	200	285	355	380
15 °/₀ of water .	55	100	150	170

Another series of trials made at the Laboratory at Copenhagen a few years before at the request of the Danish State Railways gave the following results :

1 : 3 concrete.	After 3 days.	After 7 days.	After 28 days.
	Kgr. per cm².		
8 °/₀ of water . .	183	332	518
12 °/₀ of water . .	41	86	151

In the last series of tests the difference in the strengths of the concrete is even more striking than in the first series. It will be seen from these experiments that increase in quantity of water reduces the resistance to crushing, in the first instance by three-fourths and that, even after six months, the strength of the concrete containing excess of water does not attain one half of the strength obtained with the smaller percentage of water.

In relation to the adhesion between iron and concrete, the addition of excess of water in the preparation of concrete plays the same part, so that the adhesion is greatly diminished when the quantity of water in increased.

It is not always easy to supervise the mixing of the concrete so as to ensure that the added water is correct in quantity. Actually the construction of most of the works in concrete is carried out by contract and the wetter the concrete the more easily is the work carried out. For this reason the workmen always have a tendency to add more water than is necessary and even with the strictest supervision it is difficult to prevent them from so doing.

With regard to the *mixing of the concrete* the quality of this, as is well known, plays a great part in its strength. It may, however, be possible to eliminate almost all uncertainty in this respect by mixing the concrete by machine; this is almost always done in Scandinavia when large works are in question. If, under exceptional conditions, it should happen that it is mixed by hand, in the case of structures for which it had been intended to use a concrete mixer (in case of accidental breakdown of the machine for example) it is usually required that the concrete should be composed of a much richer mixture than had been specified.

CHAPTER III.

Scheme for a structure in reinforced concrete and the execution of the work in practice.

It follows from the preceding that there are a large number of factors likely to cause trouble, either when it is a question of the selection of the materials or later in the preparation of the concrete and we have seen how great may be the variation in the strength of the concrete due to variation of conditions in these cases.

If, by chance, several mistakes are made at the same time, this may prove absolutely dangerous to the structure and in any case the factor of safety (3 to 5) on which one may generally count no longer exists.

Considering the variations in the stresses on the iron and particularly in the resistance of the concrete to crushing which are brought about by conditions arising on the site, it would appear that there is often no relation between the final stress on the concrete as erected, and the stress used in the calculations made during the design.

It is, of course, necessary to calculate the dimensions of the structure, to decide what should be the thickness of the concrete, the quantity of iron in it, etc., but the calculations are often made with a meticulous accuracy quite out of keeping with the actual conditions. Time is wasted in ascertaining whether the stress on the iron is 40 or 42 kgr. per cm^2 (569 or 597 lb. per square inch) or whether a round bar 18 mm. (23/32 inch) in diameter may in some places be replaced by a bar of 16 or 17 mm. (5/8 or 11/16 inch) in diameter; account is not taken of the numerous, varying conditions existing on the site, conditions which however, in many cases render the results of calculations somewhat misleading.

Moreover this attempt at economy of iron often leads to trouble particularly when it is a question of use of many bars of different dimensions in the same concrete structure. Because one girder or one slab is possibly less heavily loaded than the adjacent girder or slab this must not be taken as a reason for immediately reducing the dimensions of the iron; this, only too often, leads to trouble on the site.

In the schemes for a structure of reinforced concrete there is a tendency to exaggerated economy in the selection of the diameters of the iron bars, as well as in the determination of the length by which the bars are anchored to the concrete and of the length (at the joints) by which the bars overlap each other. In structures entirely of iron this economy is not pushed so far although in this case one is much more certain that the work will be carried out exactly in accordance with the drawings, than one is in the case of a reinforced concrete structure in which the bars are very often displaced.

In an iron structure each detail *should be* exact, for otherwise it will be impossible to assemble the details of the structure; but, on the other hand, in structures of concrete the reinforcement is not rigidly secured; the round bars and the stirrups are easily covered by the concrete even though the bars are not in their right places, are wrongly bent, or have other defects. Moreover, the formation of the reinforcement, the placing of this in the shuttering, the securing of the stirrups, etc. (not to mention the actual filling in), are entrusted to workmen and foremen, men without as much education in this branch as have the workmen in an engineering firm; yet, nevertheless, a

structure of reinforced concrete requires exact knowledge, and the greatest care if one desires to obtain a good result.

In designing a structure of reinforced concrete the engineer entrusted with the production of the detailed drawings should always remember these circumstances, and the design should always be worked out in such a manner that errors which may easily be made on the site shall not prove a menace to the strength of the structure. If the design is such that it is important, for the safety of the structure, that some parts of it should be executed with special care, — either as to the placing of the reinforcement, or in the filling in of the concrete, — this should be specially noted on the drawings.

In all cases the engineer who deals with the design should remember that, on the site, there is nothing to work from but the drawings, and that consequently these should give all the particulars necessary, for ensuring the strength of the structure.

A few examples, illustrating the remarks that have been made, follow :

First example :

In a cantilever (bracket) girder (fig. 1) the tension rods have been bent at the

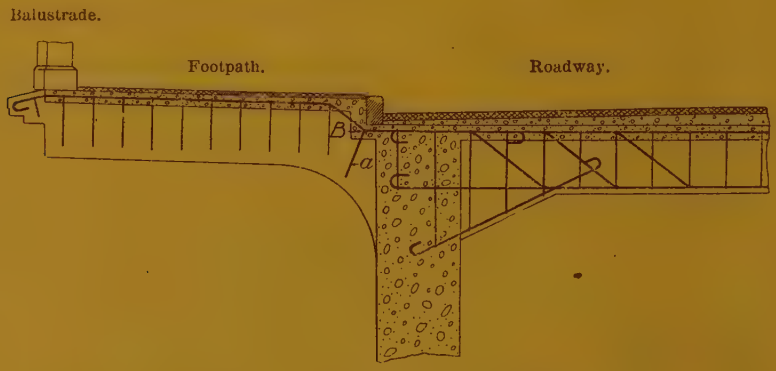

Fig. 1. — Corbelled girder (bracketed).

ends ,and the upper part of the curve B of the downward bend of these is attached to the stirrups *a*.

This form of construction may be justified from the theoretical point of view in the case when the stirrups *a*, are firmly fastened to the iron; but if, on the other hand, this is not the case—if, for example, the stirrups should lift during the filling in of the concrete or if they are displaced towards the right, away from the summit of the curve of the bar, — the loading of the bracket will have the result of slacking the lower part of the tie-rods, and the bracket will yield.

This is the reason why a form of construction such as the preceding makes it absolutely necessary that the drawings should show that at the point B, there is a « danger point » which requires special care and attention in the execution of the work (1).

(1) It may generally be stated that the strength of a structure that depends on certain stirrups being placed correctly is always doubtful and that where

Second example :

In a two-span bridge, a girder of reinforced concrete is reinforced as shown in figure 2. The reinforcing bars (1) for the left-hand span finish at the point B and are jointed to the reinforcing bars (2) of the right-hand span, in such manner that the bars overlap on the length A-B which is that strictly theore-

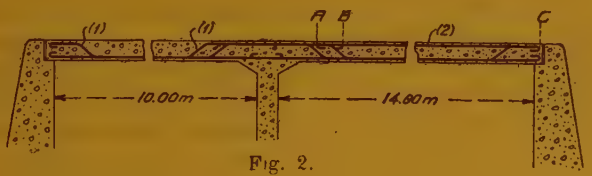

Fig. 2.

tically required. When the iron bars 1 are ready and placed in the shuttering it happens that the ends of the bars B do not come exactly where they should, but more to the left, by 30 to 40 cm. (12 to 16 inches) for instance, and if the bars 2 are at the same time so displaced that the right-hand ends are exactly in position, the length of overlap A-B is reduced to a minimum — if this overlap exist at all.

It is not always easy to ascertain such an error and it is very rarely discovered by the workmen or foreman who do not know that the two bars have been treated in the calculations as forming one bar only. In this case the drawings should give particulars from which it can be seen distincly that the length of overlap A-B must be obtained absolutely; it would be preferable that the bars 2 should be shortened at the other end C of the girder.

Third example :

It often happens that a reinforced concrete structure has been properly designed, but badly carried out on the site without it being possible to say that the work has been carried out with want of care, the errors arising entirely from want of particulars on the detailed drawings.

This is very liable to occur when a reinforced concrete structure is of such design that the stopping of the filling in at the wrong place may endanger the structure, or in any case upset the calculations on which it is based.

A structure of this class in shown in figure 3.

A girder is *anchored* in a concrete

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there is a bend in a girder it is advisable to allow some of the rods to continue in a straight line.

A girder like that shown in figures 1*a* or 1*b*

Fig. 1*a*.

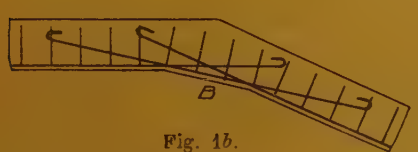


Fig. 1*b*.

should be reinforced as shown in the figures; the irons are « jointed » at the summit of the angle B; it is necessary, moreover, that the distance from B to the end of the irons should not be more than the length necessary for anchoring the irons in the concrete.

wall and the junction of the parts is arranged in such manner that the bar *a* of the rear surface of the wall and the raised bars of the girder *b* overlap over the necessary length of from 30 to 40 times the diameter of the bar.

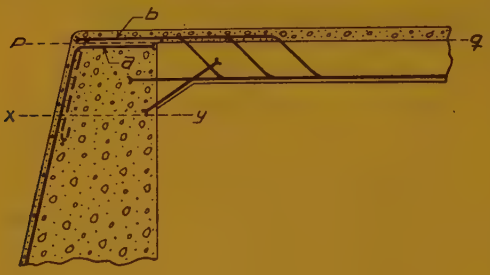


Fig. 3.

If the filling in of the concrete structure is performed by first raising the walls up to the line *x-y*, and then the body of the wall and girder up to the line *p-q* (under-surface of the floor) and finally the floor itself and at the same time the raised bars *b* are buried, the filling in has been done quite wrongly for no anchorage effect will be obtained between the girders and the wall.

At the line *p-q*, at which the filling has been stopped, a crack will invariably be formed and there will consequently be no junction between the parallel bars *a* and *b*, and it is just this junction which forms the basis of the anchored structure.

If on the other hand the filling is performed in such manner that the bars *a* and *b* are covered at the same time, the structure is quite safe if the concrete is good.

In fact it is inexcusable in such a structure to count on total or partial anchored construction if no special remarks are made on the drawing to show the manner in which the filling must be carried out. The structure should be so designed as to avoid any danger arising from an error in stopping the filling in, and, in the case in question, the management of the railway requires an increase in the length of the reinforcement of the girders down the back surface of the walls amounting to about 1.25 m. (4 ft. 1 in.) (approximately as shown by the dotted line) in such manner that the contractor is almost compelled to fill in the two layers covering the iron at the same time.

The increase in expense necessitated by the lengthening of the reinforcement bars as shown above must not be taken to be serious, when compared with the great increase of safety obtained thereby.

Fourth example :

A structure shown in figure 4, where a (bracketed) footpath slab is entirely held up by a series of round bars 10 mm. (3/8 inch) in diameter, which cover the reinforcement of the bracket for a length of 20 to 25 cm. (8 to 10 inches), is also not satisfactory.

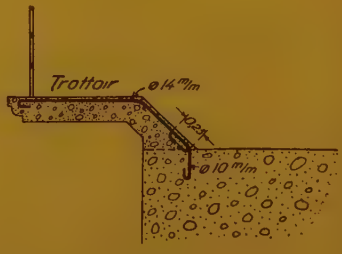


Fig. 4.

Explanation of the French term : Trottoir = Footpath.

According to the calculations the structure is strong enough, but the safety of the structure depends entirely on the good workmanship of a small prismatic piece of concrete and it could be improved at small expense, for instance by lengthen-

ing the 10 mm. (3/8 inch) bars to two or three times their length.

* * *

From the preceding one may realise that the strength and solidity of reinforced concrete structures depend on a careful design, on carefully prepared and thoroughly understood drawings, and on a scrupulously exact execution of the work. And danger will always exist if there is any doubt about either of these and particularly about the execution of the work.

It must be added moreover, as we have already stated, that in reinforced concrete structures, all checking is impossible once the filling in has been finished. Whereas with wooden and iron structures it is possible to carry out inspection at almost any time, as regards dimensions, riveting, the formation of rust, etc., but in a completed structure of reinforced concrete it is not possible to see whether the iron is properly incorporated, whether the concrete is of first class quality, whether the stoppages of the filling in have been suitably arranged, or whether the concrete has set too rapidly, so as to produce stresses due to the setting contraction.

So far as the strength of the structure is concerned it is more important in this than in any other class of work that a large part of the responsibility should be transferred from the constructional engineer's office to the site; this perhaps, involves greater anxieties because, as so many examples show, the contractors and the master masons, who are not in the possession of the necessary technical knowledge of reinforced concrete structures undertake the execution of such work without due consideration simply because the work appears easy and does not seem to demand skilled training such as smith's or carpenter's work requires.

Consequently, when *conclusion 2 of 1905* states that there is no occasion for anxiety regarding structures of reinforced concrete and that their use may be recommended to railway administrations, we think — notwithstanding the general truth of this conclusion — that certain reservations should be made; particularly when it is a question of knowing the class of structure for which the use of reinforced concrete is recommended.

With regard to *conclusion 5* which stated that the use of reinforced concrete enables the execution of the work to be performed rapidly, we think that here also a reservation should be made in all those cases which concern Denmark.

As is know, Denmark receives the iron which it uses from abroad, and we have often seen that when it has been a question of large structures of reinforced concrete in which round iron bars of large dimensions have been required (or reinforcement of special bars, for exemple large notched bars), the foreign works have not been able to complete deliveries of bars except after a delay of six or eight weeks.

If to this we add that the climate of the northern countries does not allow of work being executed on such structures except for two-thirds or three-fourths of the year, it very often follows that a reinforced concrete structure takes a much longer time to erect than a similar structure of iron or of wood.

PART II.

The use of concrete and reinforced concrete on the railways of the Scandinavian countries.

CHAPTER IV.

Foundations.

The use of concrete for foundations is general in all the three Scandinavian countries, both with regard to foundations in ordinary concrete and those in reinforced concrete.

In most instances those of the first type are not of great interest and are only used where the ground is good. Formerly the mixture for the cement was generally 1 : 4 : 8 (1 part of cement + 4 parts of sand + 8 parts of broken stone) or 1 : 3 : 6, but in practice it is often 1 : 4 : 7 or 1 : 3 : 5 because experience has shown that, if a sufficient quantity of mortar is used, a much better concrete is obtained without increase of cost. It is of particular importance to use sufficient mortar because when one of the materials consists of broken stone the percentage of the voids is, as is well-known, much greater than in the case of pebbles; and if care is not taken there is the risk of obtaining a permeable concrete (with cavities).

If the ground on which the foundations are to be laid is bad, iron is generally used in the concrete.

Formerly in such cases, old railway rails were used with joists or other ironwork to strengthen the foundations. This is now less frequently done, because the high cost of iron renders it too expensive; the same reinforcement can be obtained at lower cost and with greater certainty, by the rational use of thin round iron bars properly placed.

Foundations laid on ground of poor supporting power are generally constructed by enlarging the footings, so that the pressure exerted on the ground may be spread over a larger area; or if this cannot be done some piles of reinforced concrete or of ordinary concrete are driven down to the solid ground and these are connected at the top by arches, girders or other methods. If this cannot be done a foundation on piles is usually adopted.

These three methods of executing foundations are very often used in Scandinavia.

Continuous inverts which serve to distribute the pressure exercised on bad ground over a greater area are often used in the construction of locomotive pits and repair pits, the base being enlaged in cross section and reinforced in such manner that it is capable of distributing the pressure over the ground (fig. 5, see also figs. 67, 69 and 70).

It has also frequently been necessary to construct continuous inverts when it has been a question of a large culvert or of a drain under a railway embankment.

Figure 6 shows a subway 5 m. (16 ft. 5 in.) in width constructed by the Danish State Railways under a railway embankment south of Vejle (Denmark). During the execution of this subway it was found that the sub-soil was not good and for this reason an invert of ordinary concrete (with tension bars embedded in the concrete) was constructed.

Similar cases have arisen in many places, but instead of an invert in ordinary concrete a flat base was constructed

suitably reinforced to resist the pressure from below.

In some cases, both in Sweden and in Denmark, small stone houses have been

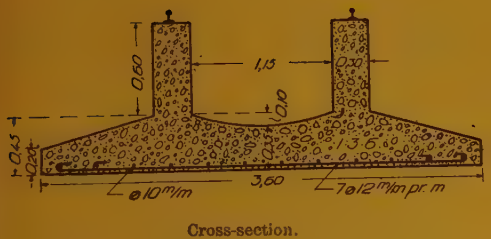


Fig. 5. — Working pit with ordinary invert (Southern Fionian Railways, Denmark).

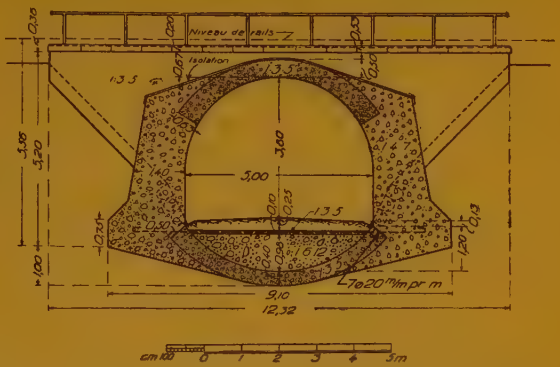


Fig. 6. — Subway 5 m. (16.4 feet) wide carried on an invert of ordinary concrete (Danish State Railways).

Explanation of French terms : 7 ∅ 12 m/m pr. m = 7 bars 12 m/m dia. per metre. — Niveau de rails = Rail level. Isolation = Protective covering.

Fig. 7. — Reinforcement of a pile (Danish State Railways).

built on foundations consisting of a continuous raft of reinforced concrete. This method is rarely economical, but it has sometimes enabled the foundation to be

executed more rapidly than would have been the case if made on piles which would have had to be prepared specially.

If a structure must be built on bad subsoil, and where the solid foundation lies at a great depth it is necessary to have recourse to *piling*.

Piling with reinforced concrete piles is largely used in Denmark and in Sweden, but very little in Norway. Rectangular piles of reinforced concrete are nearly always used; they are pre-cast and are driven afterwards. They are generally of square section varying from 18×18 cm. to 36×36 cm. (7×7 inches to 14×14 inches) and of a length of as much as 10 or 12 metres (32 ft. 10 in. or 39 ft. 4 in.). In one case in Sweden piles of greater length were used for the foundations of the bridge over *Ore älv*, 1917-1919 (Swedish State Railway); these were as much as 15 metres (49 ft. 3 in.) in length.

The reinforcement of the piles is connected by cross stays; hooping is not used. The lower end of the piles is generally fitted with a wedge-shaped end covered by a thin plate of iron (fig. 7) which forms a simple and cheap « shoe ».

The mixture for the cement varies from 1 : 1.25 : 2.5 to 1 : 2 : 3, and it is only in a very few cases that poorer concrete than the mixture 1 : 2.5 : 3.5 has been used. A sand concrete in the proportion of 1 : 3 is also used for piles especially in Sweden.

In the greater number of cases the driving is effected when the piles are from four to six weeks old and in Denmark a pad is nearly always interposed between the monkey and the head of the pile. After the driving has been completed the iron bars which project from the end of the piles are cleared of concrete in order that a good connection may be made with these when the foundation is laid.

Among the advantages of reinforced concrete piles, must be mentioned their durability (which is the same on dry ground as when driven through damp strata); they can moreover carry heavier loads than wooden piles. It is also possible to make them of very great length and even to lengthen them if they should prove too short in the course of driving. This happened on the Danish State Railways in the case of the foundations for a bridge at Kolding (Jutland) where some concrete piles measuring 10 metres (32 ft. 10 in.) long and 25×25 cm. (10×10 inches) in cross section, reinforced with four round bars 20 mm. (25/32 inch in diameter proved too short on driving; after the piles had been driven an extension of from 4 to 5 metres (13 feet to 16 ft. 5 in.) was moulded, and after leaving for 28 days to harden the driving was continued without any difficulty. This foundation was carried out in 1919-1920.

A special form of piling in ordinary concrete is sometimes used by the Danish State Railways. Holes about 50 cm. (20 inches) in diameter and of a depth of up to 5 m. (16 ft. 5 in.) are bored with an ordinary borer; concrete is then poured into these holes.

Simplex piles are not used in Denmark or in Norway, but are in use in Sweden. We may quote as an example the foundations of the large viaduct at Malmö (1916). In this case 567 piles each 8 metres (26 feet) in length were used; they were 36 cm. (14 inches) in diameter and were made of a 1 : 2.5 : 2.5 mixture.

The oblique piles only contained reinforcement; the vertical piles had none. The load per pile was calculated at about 35 tons.

Caissons and wells of concrete are rarely used for foundations by the Scandinavian railways, the only exceptions being in the case of two beacons.

CHAPTER V.

Culverts, aqueducts, bridges, tunnels and structures of the same kind,

In the Scandinavian countries large and small culverts, aqueducts, bridges and structures of this class have been built to a great extent of concrete with or without reinforcement.

a) *Culverts, aqueducts, etc.*

In the case of culverts built *under roads*, slopes or otherwise, it is permissible, in Denmark, to use cement pipes, provided that these are well made and have matured for at least three months. The pipes must be able to carry a pressure of at least 7 t. 5 per m² (1 536 lb. per square foot) area of horizontal cross-section calculated as the product of the diameter and of the outside length of the pipe exclusive of the socket.

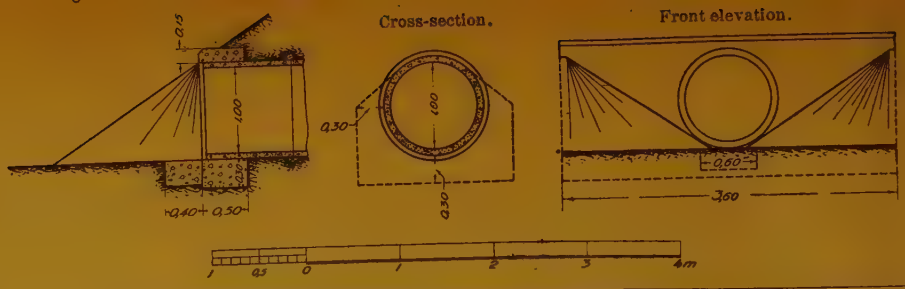
For culverts constructed under *railways*, « Monier » pipes are used up to a diameter of 1 m. (3 ft. 3 3/8 in.) these pipes must be well made and have matured for at least three months. The dimensions are given in figure 8; the dotted line in the figure shows a thickening of the pipe (a covering of concrete) which is used under embankments more than 3 m. (10 feet) in height or under conditions in which the ground is liable to compression. The table accompanying the figure shows the dimensions and arrangement of the iron used in the pipes for bores varying from 40 to 100 cm. (1 ft. 3 3/4 in. 3 ft. 3 3/8 in.).

When the internal diameter of the pipes exceeds 1 m. (3 ft. 3 3/8 in.) but is less than 1 m. 25 (4 ft. 1 in.), culverts are generally made of which the sides and the bottoms consist of blocks of stone, but with the top of reinforced concrete; the reinforcement generally consists of old rails or round bars. When the aqueduct is of greater size and exceeds 1 m. 25 in bore, it is constructed as a tunnel of ordinary concrete cast « in situ ». A tunnel of this class is shown in figure 9. This section is also used in Norway and in Sweden.

As an example of a circular tunnel of large dimensions, that in reinforced concrete proposed by the Norwegian State Railway, 4 m. 66 (15 ft. 3 1/2 in.) in diameter for the deviation of the Loelven torrent may be mentioned. The cross-section is shown in figure 10. The tunnel rests on a foundation of concrete and is protected externally. The total length of the tunnel is about 1 km. 5 (0.93 mile) and the gradient is 9.3 per mil.

In Denmark as in Sweden, large culverts are generally constructed as concrete *arches*, with or without reinforcement, whereas they are more rarely constructed in this manner in Norway. Figure 11 shows an arched tunnel, of ordinary concrete, constructed by the Danish State Railways under a railway embankment about 15 m. (49 feet). in height. The arch has an opening of 5 m. (16 ft. 5 in.); the side-walls and the foundations are of ordinary concrete; there is no invert to the tunnel, but at intervals buttresses have been formed to act as supports to the foundations. The structure is divided into three parts by joints which separate it vertically as shown in the figure; the upper surface is protected by bricks soaked in tar.

The Swedish State Railways have very often made use of arches of reinforced



Internal diameter, in millimetres.	Thickness, in millimetres.	Internal reinforcement		External reinforcement		Number of distributing bars : 3 millimetres.	Length in metres.	Weight per pipe, in kilograms.
		Maximum permissible distance between the rings, in millimetres.	Thickness, in millimetres.	Maximum permissible distance between the rings, in millimetres.	Thickness, in millimetres.			
40	40	50	3	50	3	8	1	132
50	45	50	3	50	3	11	1	185
60	50	50	5	50	3	11	1	240
80	55	50	5	50	5	12	1	356
100	60	45	5	45	5	14	1	480

Fig. 8. — Reinforced concrete pipes (Danish State Railways).

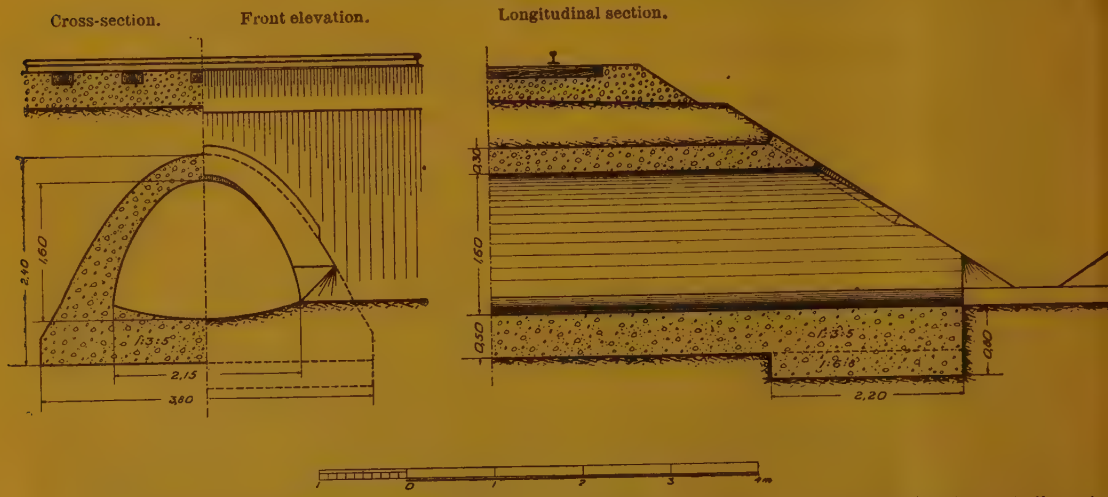


Fig. 9. — Arched aqueduct (culvert) 2 m. (6 ft. 6 3/4 in.) wide of ordinary concrete (Danish State Railways).

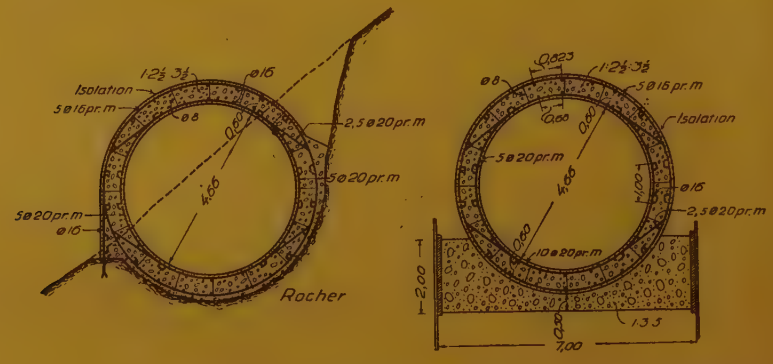


Fig. 10. — Circular drain 1 km. 5 (0.93 mile) in length, of reinforced concrete (Norwegian State Railways).

Explanation of the French term : Rocher = Rock.

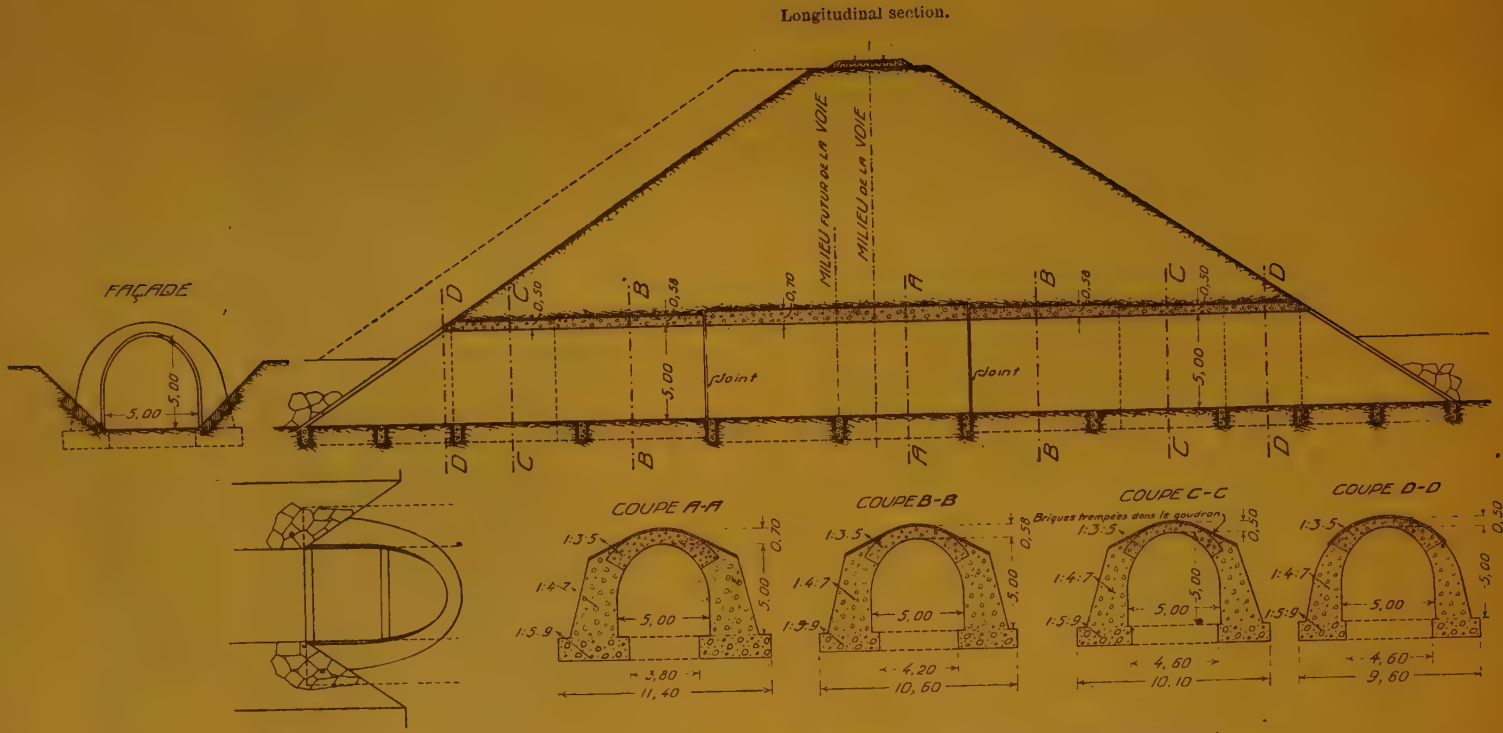


Fig. 11. — Arched culvert 5 m. (16 ft. 5 in.) wide of ordinary concrete (Danish State Railways).

Explanation of French terms. Façade = Front elevation. — Coupe = Section. — Joint = Joint. — Milieu futur de la voie = Future centre of the track. — Milieu de la voie = Present centre of the track. — Briques trempées dans le goudron = Bricks dipped in tar.

concrete with reinforcement in the sides and at the bottom; in such cases, the opening varies from 3 to 5 m. (9 ft. 10 in. to 16 ft. 5 in.). In figure 12 for example will be seen an arched tunnel 5 m. (16 ft. 5 in.) span constructed by these railways for the « Nykvarnsan ». The Swedish State Railways have also used structures of the form of a rectangular closed frame of reinforced concrete. Lastly one must add that the Swedish State Railways have constructed a number of straight culverts, with walls and bases of granite, covered with reinforced concrete according to standard drawings which were specially prepared.

b) *Road bridges and foot-bridges.*

Bridges with straight girders. — As the result of the continual expense incurred in the necessary supervision of railway crossings and of the road and foot-path crossings (level crossings), and also with a view to obtaining safety for the traffic, the Danish State Railways during the last few years have commenced to replace level crossings, to a great extent, by subways or over-bridges. These new road bridges are almost always constructed of reinforced concrete. Since 1910 the Danish State Railways have constructed about 70 bridges with straight girders (over-bridges) as shown in figure 13. The width of the over-bridge is from 4 to 5 m. (13 ft. 2 in. to 16 ft. 5 in.) and the centre spans have two or three columns each. The concrete mixture is 1 : 2 : 3 except in the foundations where a mixture 1 : 3 : 5 has been used. Regarding the permissible stresses on concrete and on the iron we will refer to chapter IX. An evenly distributed load of 400 kgr. per m^2 (81.92 lb. per square foot) and also a 20-ton steam roller are taken as a basis for the calculation. The surface of the concrete which forms the end of the embankment of earth, or of the roadway is doubly protected with a coat of asphalt laid cold.

In similar cases the Norwegian State Railways have used a flooring of reinforced concrete resting on iron girders. With regard to the Swedish State Railways these have constructed the greater part of the road bridges as arched bridges, reference to which will be made later. As an example of a large road bridge, constructed by the Swedish State Railways by means of straight girders, we will refer to figure 14. The bridge consists of a reinforced concrete platform placed between two main girders of reinforced concrete which also form the parapet of the bridge. It has a span of 17 m. 4 (57 ft. 1 in.) and the girders are fitted with sliding bearings at one end.

Large road bridges, constructed as straight girder bridges, of reinforced concrete, have been built in many places by the Danish State Railways. The oldest of these bridges is the road bridge shown in figure 15, which crosses over the central railway station at Copenhagen. It was constructed in 1906, has a length of 128 metres (420 feet) and a width of 19 m. 5 (64 feet); the girders have a fixed bearing on the central pier and continue thence on both sides over six spans to the abutments where they rest on sliding bearings. The bridge, apart from the piers, is supported by bearers carried on groups of columns, each of which consists of three columns the base of which rest on steel bed-plates and at the upper end support (also by bed plates) the cross girders corbelled at both ends and carrying the main girders. The bed-plate shown in figure 16 has a length of 78 cm. (2 ft. 6 3/4 in.) and a width 25 cm. (9 3/4 inches).

Another important bridge with straight

Fig. 12. — Aqueduct (culvert) 5 m. (16 ft. 5 in.) for the Nykvarnsän (Swedish State Railways).

Fig. 13. — Road-bridge 17 m. 4 (57 ft. 1 in.) of reinforced concrete (Swedish State Railways).

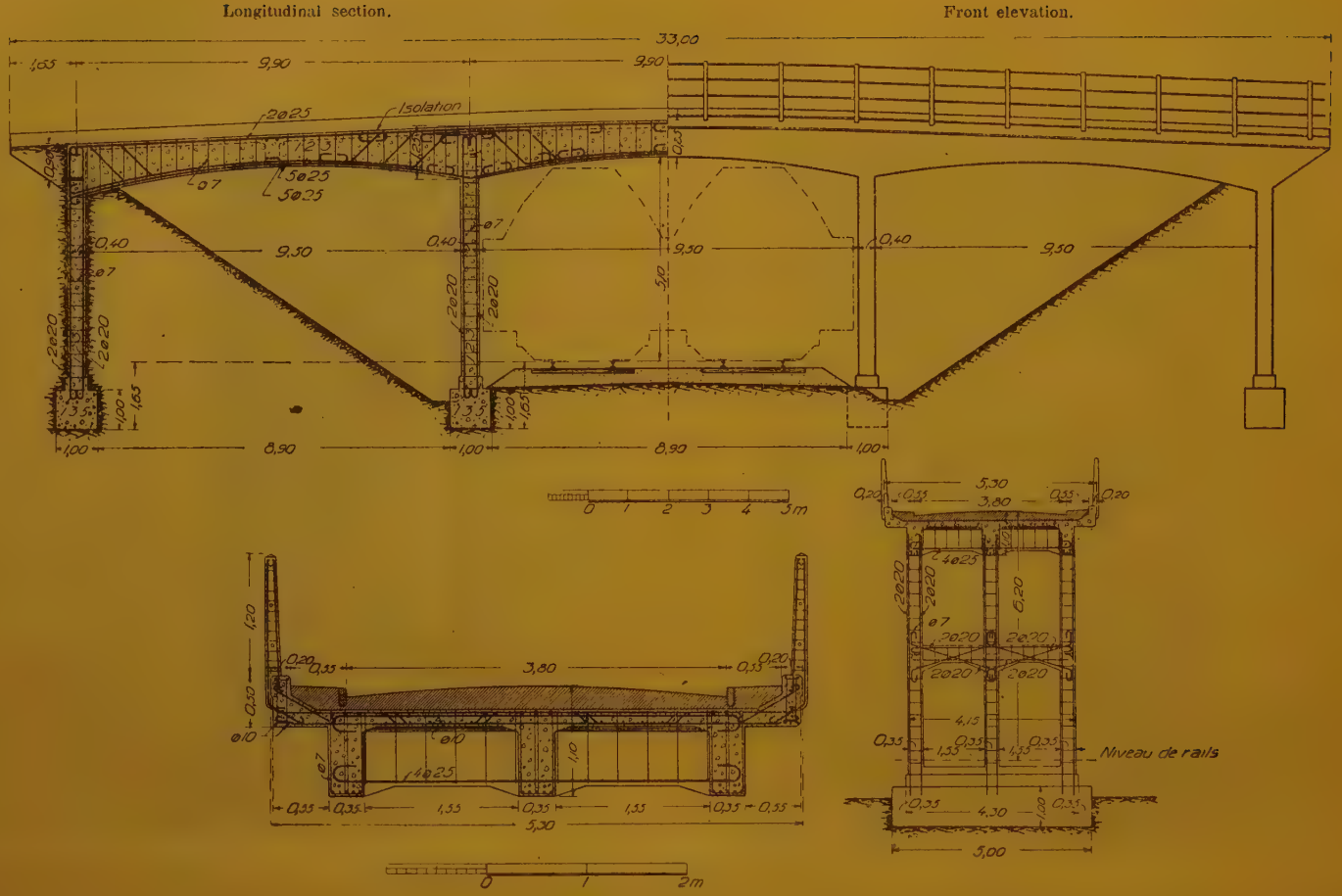


Fig. 14. — Standard small foot-bridge (straight girder bridge) (Danish State Railways).

Explanation of French terms : Isolation = Protective covering. — Niveau de rails = Rail level.

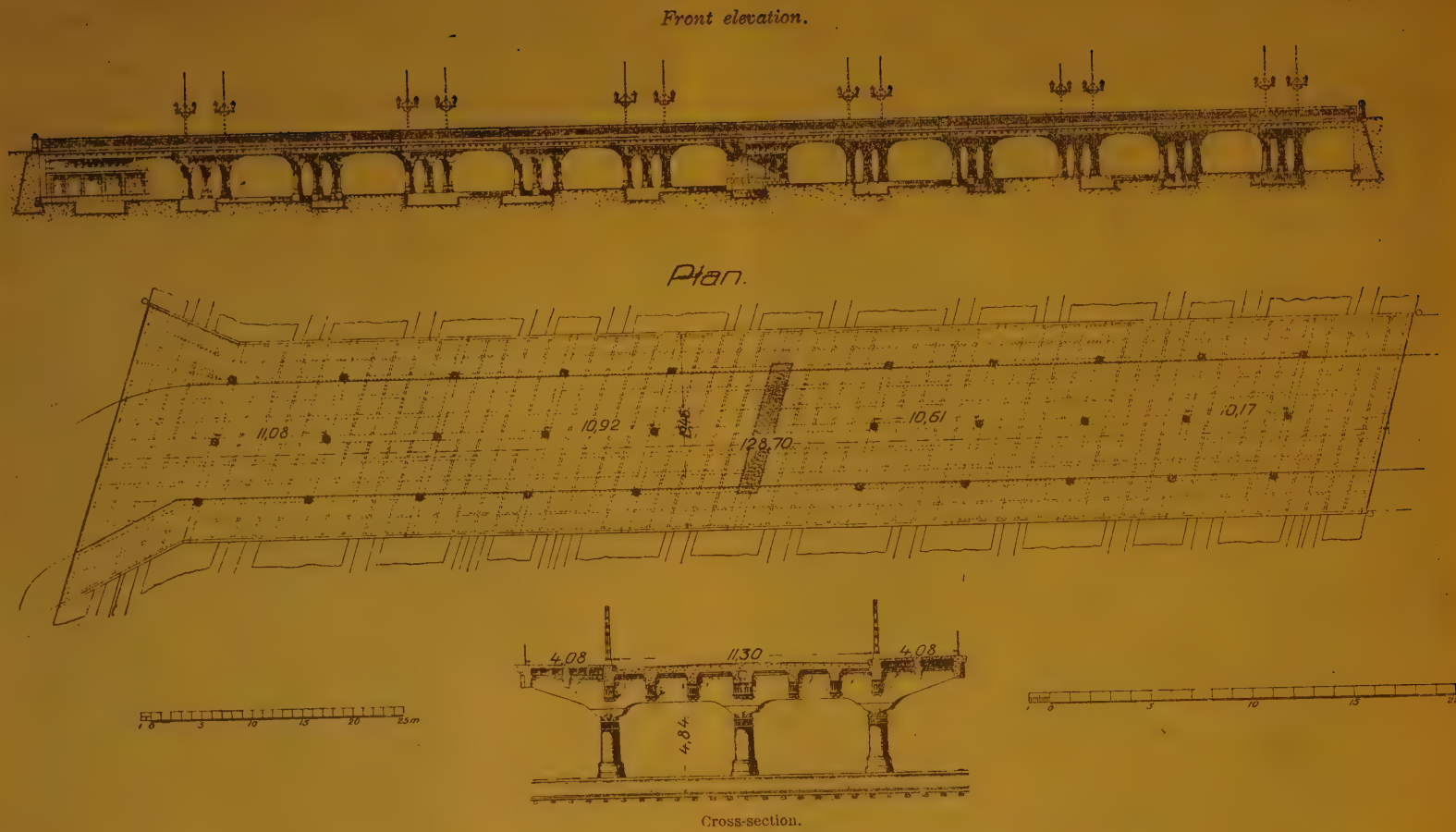


Fig. 15. — Road-bridge over the Copenhagen Central railway station (Danish State Railways).

Fig. 16. — Steel cradles for vertical columns (Danish State Railways).

Fig. 17. — Copenhagen Central station (Danish State Railways).

girders which may be mentioned was that constructed of reinforced concrete at Copenhagen in 1909-1910. This supports the space in front of the central station at Copenhagen and the two roads that lead to it. As shown by figure 17 the railway station buildings are arranged transversely across all the railway tracks and platforms and for this reason it was necessary to construct the yard and roads as bridges. The yard has a superficial area of 4 800 m² (51 700 square feet) and the two roads each measure about 1 200 m² (12 925 square feet). The bridges are divided into separate parts by expansion joints with which we shall deal in Chapter XI.

To the north of these roads there is « Vesterbrogade » (a main street) which also crosses over the railway tracks. The bridge has a length and width respectively of 56 and 78 m. (184 and 256 feet). As the depth of the structure (about 85 cm. [2 ft. 9 1/2 in.]) was very small in proportion to the span of the girders — (about 16 m. [52 ft. 6 in.]) and for the load for which the bridge had been designed (a 23-ton steam roller and in addition a row of 12-ton lorries the whole of the load being increased by 25 per cent to allow for the effect of shock) — the form of construction adopted for the bridge was that of continuous girders which were at the same time anchored in the abutments. Figure 18 shows a longitudinal section of the bridge in which the anchored construction of the girders at the abutments can be seen. Figure 19 shows the bridge seen from below; the illustration shows that the girders are widened over a portion of their length where they rest on the centre piers, so as to be the better able to resist the large negative bending moment.

Some months after it had been constructed a test was made by loading the bridge, with the result that the long girders (16 m. [52 ft 6 in.] in length) only showed a deflection of 0 mm. 7 (1/32 inch.) at the centre. This bridge was constructed in 1910-1911.

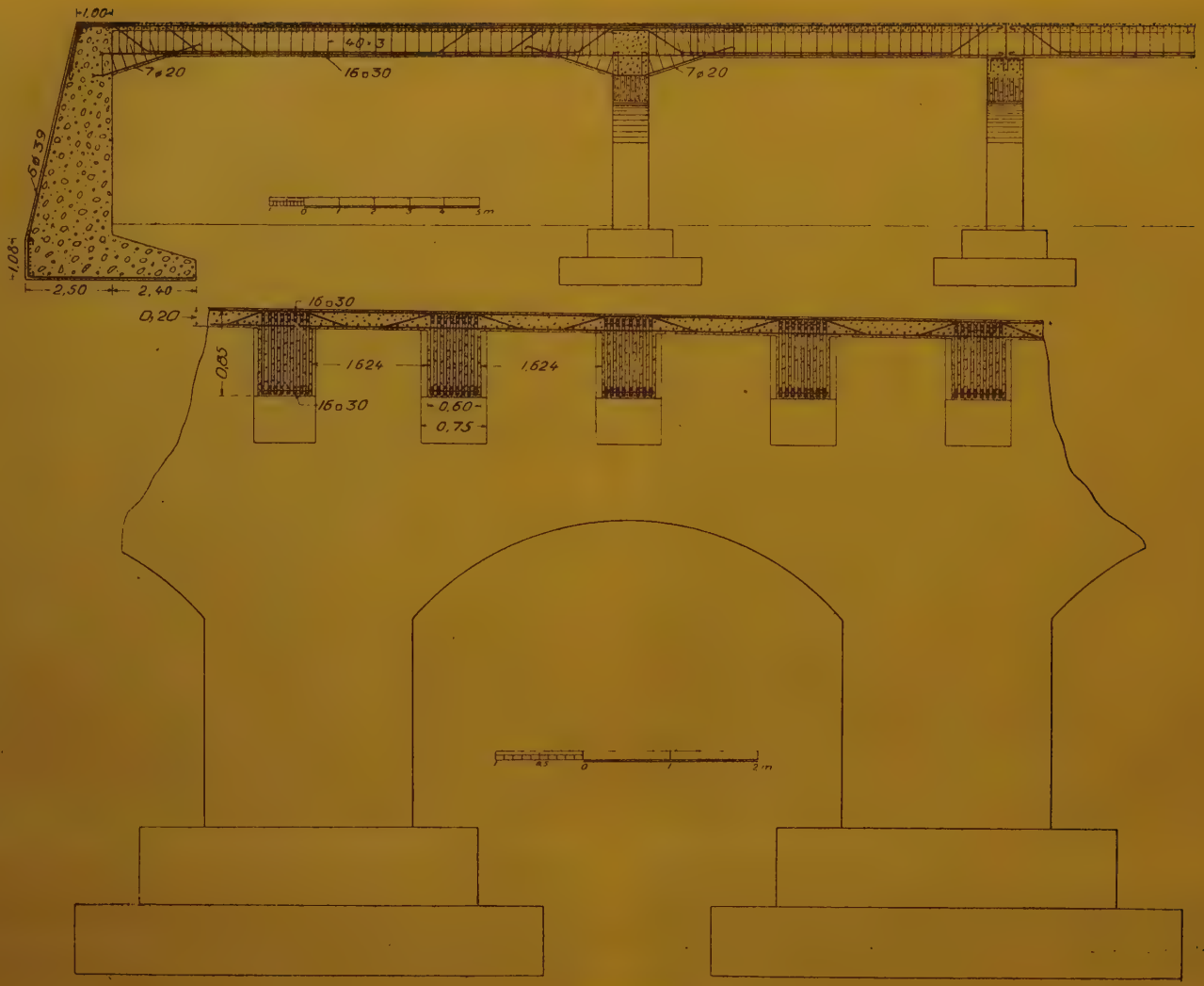
Apart from these bridges there are two other almost similar road bridges crossing over the underground railways of Copenhagen. They are about 45 m. (148 feet) in length and 22 m. 6 (74 ft. 2 in.) in width. Figure 20 shows a photograph of one of these bridges; the girders are continuous over the four spans and rest at the abutments on sliding bearings consisting of two iron plates which are secured by riveted flat iron stirrups respectively to the ends of the girders and to the pillars. These two bridges were constructed in 1916.

The largest road bridge undertaken by the Danish State Railways is now being built over the new Aarhus Station (Jutland); it is 115 m. (377 ft. 3 in.) long and 25 m. (82 feet) wide. The girders carrying the structure are continuous over twelve spans; they are supported by upright columns at the middle spans and at the ends by massive piers carrying bearing plates formed by arched bearers of reinforced concrete.

Bridges with straight girders constructed on the « Visintini » system have been carried out in some cases by the Danish State Railways. We will refer, for example, to the bridge, shown in figure 21, built over the Nyborg Station (Fionia) in 1910). The length is 24.0 + 16.5 + 24.0 m. (total 64.5 m. [78 ft. 9 in. + 54 ft. 2 in. + 78 ft. 9 in. total 211 ft. 8 in.]) and the free width of the bridge is 8 m. 3 (27 ft. 3 in.). The main girders are formed as « Gerber » girders and fitted with hinge-joints in the end spans.

Another important structure of the Visintini type is the large road bridge built in 1911 over the underground railway at

Longitudinal section.



Cross-section.

Fig. 19. — Road-bridge in Copenhagen; viewed from below see fig. 18) (Danish State Railways).

Fig. 20. — Road-bridge over the Copenhagen Underground Railway (Danish State Railways).

Copenhagen in front of the Eastern railway station; this bridge has a length of about 55 m. (180 feet) and a width of 60 m. (197 feet). The platform in this case consists of Visintini girders placed quite close to each other under the roadway, but which, under the footpath, are separated from each other by 1 m. 5 (4 ft. 11 in.) and connected at the top by a slab of reinforced concrete. The transverse girders of the middle pillars are also carried out as Visintini girders the head of which is so formed that it serves as a bearing for the platform girders.

In conclusion it must be added that in some cases the Danish State Railways have constructed a road bridge over a double track railway in which the main girders are formed as « Vierendeel » girders, as shown in figure 22.

Arched bridges. — The Danish State Railways have constructed a large number of over-bridges of small dimensions (about 60) as arched bridges; figure 23 shows the normal type of bridge of this class with one span. Arched bridges of two or more spans may also be frequently seen; we may refer, for instance, to figure 24 which shows an arched bridge of three openings.

In Norway and in Sweden arched bridges have also been constructed of reinforced concrete of a type resembling that shown in figure 23; according to the particulars which we possess at present, the Swedish State Railways have constructed about fifteen arched bridges of reinforced concrete whereas the Norwegian State railways have only built a few of them. Figures 25 and 26 for example show arched road bridges built by the Swedish State Railway; that shown in figure 26 has a span of 13 m. (42 ft. 8 in.).

Amongst the large road bridges constructed with curved girders, there is an important bridge, constructed by the Swedish State Railways at Malmö (fig. 27). The main girders of the bridge consist of arches of reinforced concrete (hooped) constructed with ties embedded in the suspended platform. The total length of the bridge is : 29 m. 1 + 34 m. 9 + 45 m. 0 + 45 m. 0 + 34 m. 9 + 29 m. 1; total 218 m. (95 ft. 6 in. + 114 ft. 6 in. + 147 ft. 8 in. + 147 ft. 8 in. + 114 ft. 6 in. + 95 ft. 6 in.; total 715 ft. 4 in.) and the width of the bridge is 18 m. (59 ft. 1 in.); the distance between the main girders is 11 m. 9 (39 ft. 1 1/2 in.). The bridge is provided with fixed bearings on the two abutments and on the centre pier; the other supports of the middle spans are constructed as columns.

Apart from this large arched bridge the Swedish State Railways have built important bridges at Katrineholm and at Malmslätt; the platform of the latter is suspended in the arches by two hinged joints without tie-bars; the reinforcement of the concrete arches is in this case partially hooped.

The Danish State Railways have also constructed bridges of reinforced concrete with arched girders; we may refer for example to figure 28 which shows the road bridge situated over the station of Naestved (Seeland).

So far as we are aware neither the Norwegian railways not the Swedish railways have built foot-bridges of reinforced concrete. The Danish railways have constructed these in some cases; we may refer for example to the reinforced concrete foot-bridge with steps, shown in figure 29. Other foot-bridges constructed as arched bridges or straight-girder bridges of reinforced concrete are to be found in some parts of Copenhagen.

Fig. 21. — Road-bridge over Nyborg station (Visintini system) (Danish State Railways).

Fig. 22. — Road-bridge (Vierendeel system) (Danish State Railways).

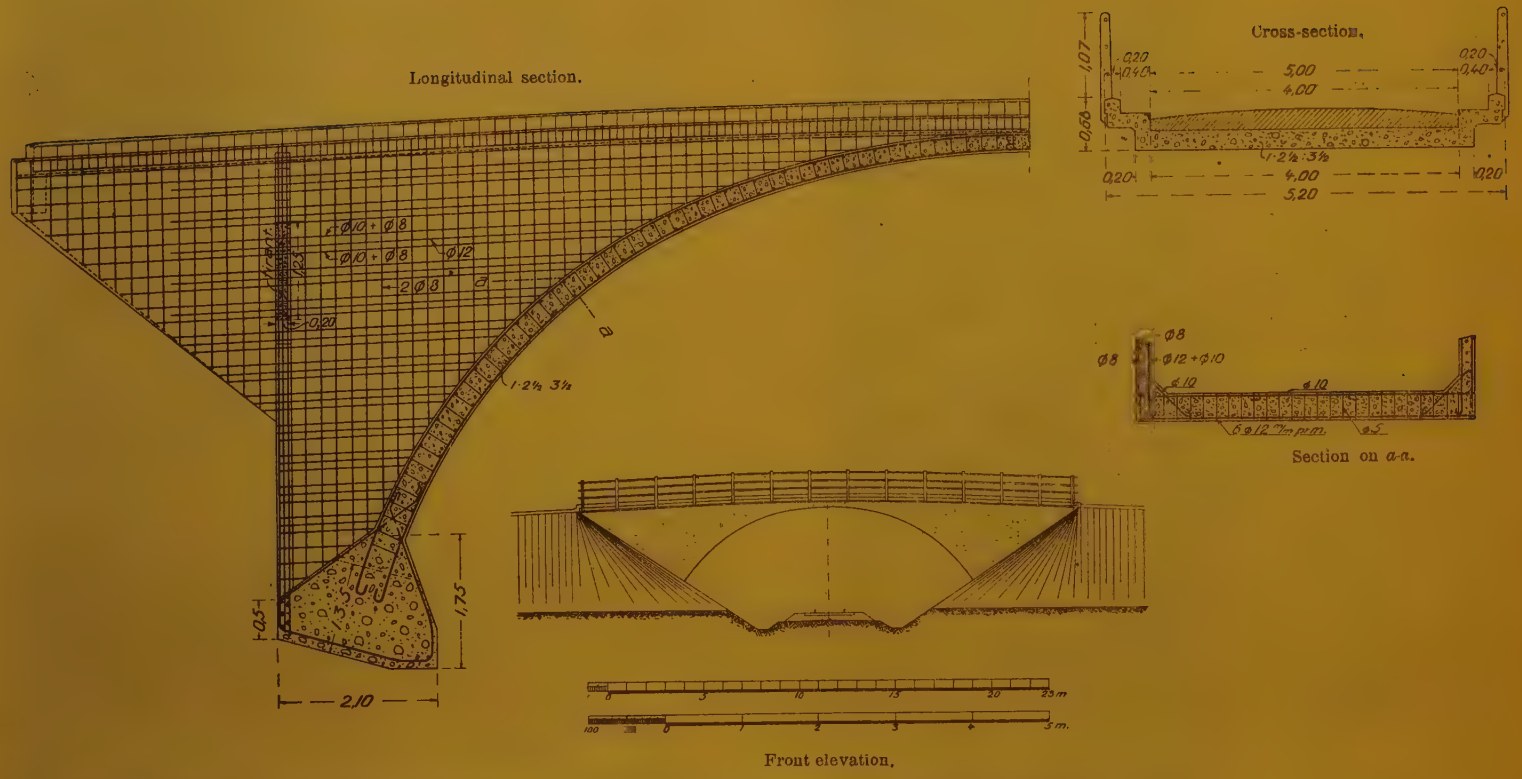


Fig. 23. — Standard small foot-bridge (single arch bridge) (Danish State Railways).

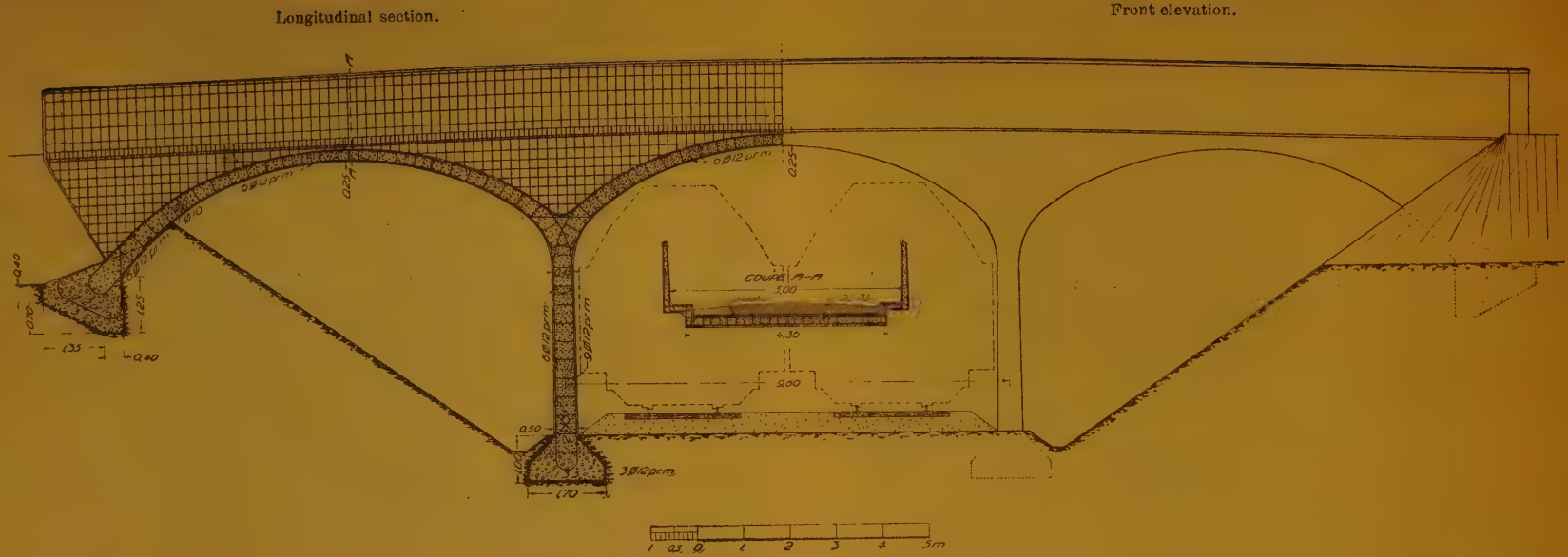


Fig. 24. — Over-bridge (three arched spans) (Danish State Railways).

Explanation of French terms : Coupe *a-a* = Section on *a-a*. — Isolation = Protective covering.

Fig. 25. — Arched road-bridge (Swedish State Railways).

Fig. 26. — Arched road-bridge (Swedish State Railways).

Fig 27. — Road-bridge over Malmö station (Swedish State Railways).

Fig. 28. — Road-bridge over Noestved station (Danish State Railways).

Fig. 29. — Reinforced concrete foot-bridge (Danish State Railways).

c) *Railway bridges.*

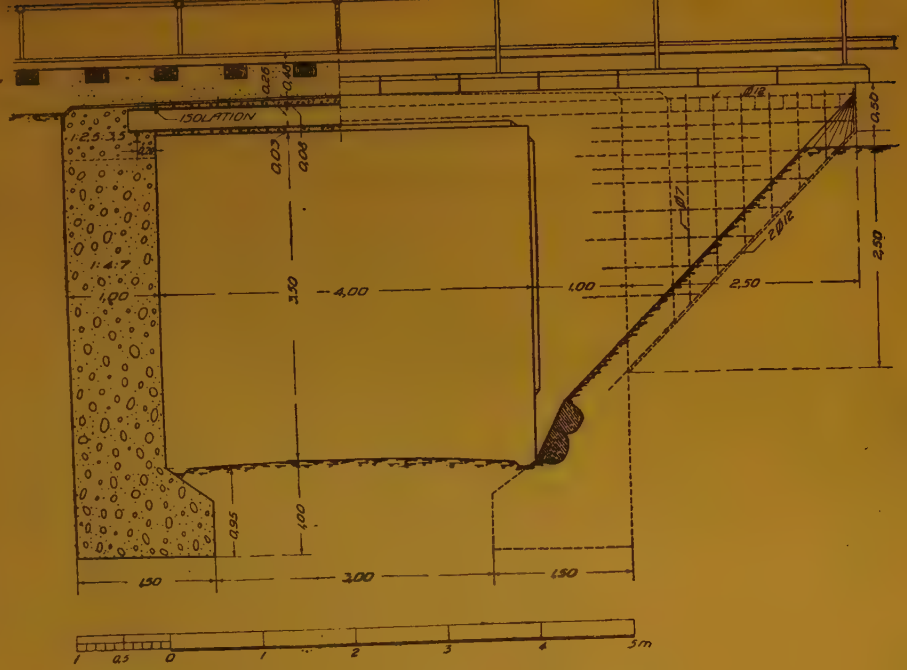
Since 1905 the Danish State Railways have constructed a fairly large number (about 300) of small railway bridges; these are constructed of piers of ordinary concrete, carrying corbelled wings of reinforced concrete, whilst the super-structure consists of rolled sections embedded in concrete (fig. 30).

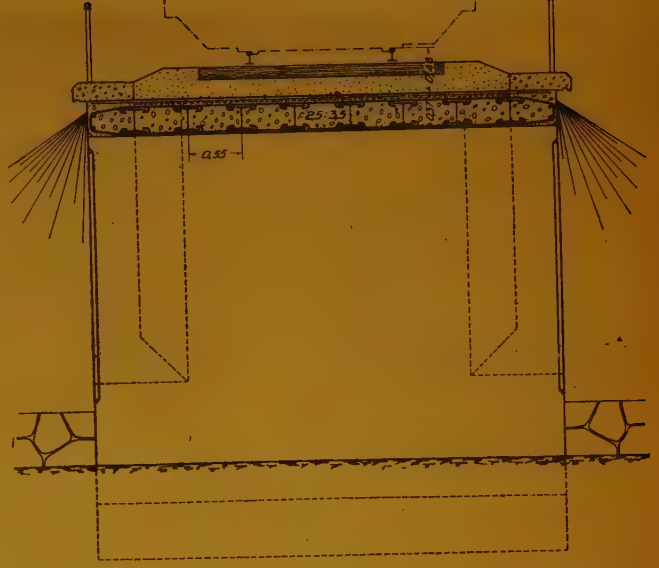
In the case of a small span (of less than 3 m. (10 feet) the superstructure has also been formed of a slab of reinforced concrete from 35 to 45 cm. (1 ft. 1 3/4 in. to 1 ft. 5 3/4 in.) in thickness instead of embedding rolled sections in the concrete as described above.

Nevertheless the greater number of railway bridges are actually constructed as *arched* bridges.

Since 1914 the Danish State Railways have constructed in all sixty railway arched bridges of ordinary concrete with spans varying from 3 to 8 m. (10 feet to 26 ft. 3 in.). Figure 31 shows, for instance, a railway bridge of this class of 6 m. (20 feet) span. In addition to these about 12 large arched bridges have been constructed in reinforced concrete having spans up to 22 m. (72 ft. 2 in.). Figure 32 shows a bridge of the type just mentioned having a span of 15 m. (49 ft. 3 in.) and a clear height at the centre of 4 m. 6 (15 ft. 1 in.); as will be seen from the figure the wings are corbelled from the arch.

The Swedish State railways have constructed a number of important works of the same class in reinforced concrete; one should, for example, mention the





Plan.

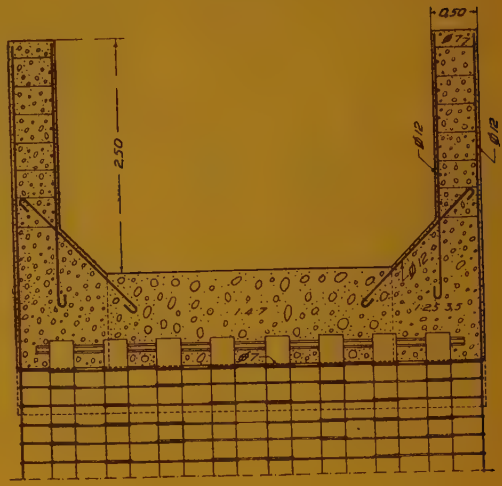


Fig. 30. — Small railway bridge with encased girders; wings of reinforced concrete (Danish State Railways).

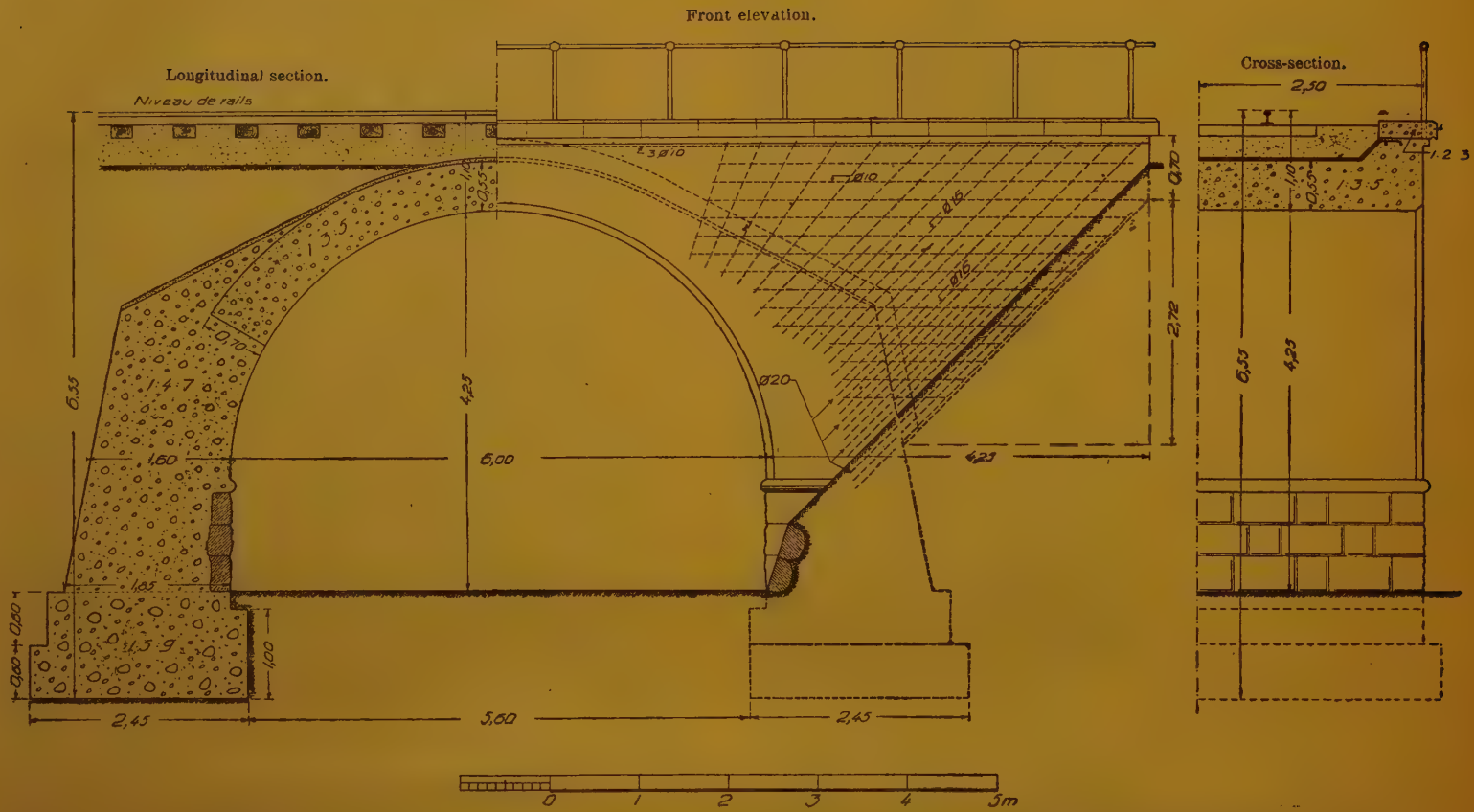
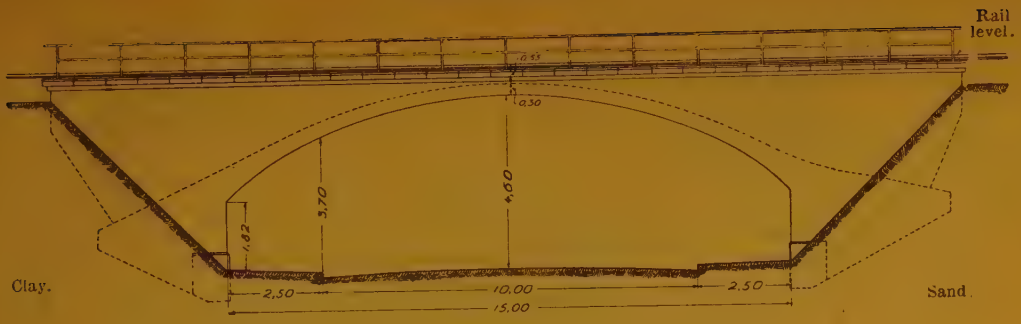


Fig. 31 — Small railway bridge, ordinary concrete arch with wings of reinforced concrete (Danish State Railways)

Explanation of French terms : Niveau de rails = Rail level.

Front elevation.



Longitudinal section.

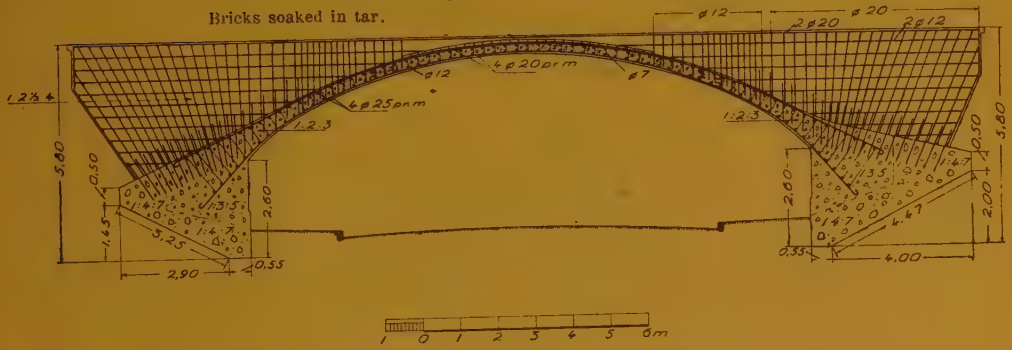


Fig. 32. — Arched railway bridge 15 m. (49 ft. 2 in.) span. (Danish State Railways).

Explanation of French terms : 4 Φ de 20 mm. p^r m. = 4 bars 20 mm. dia. per metre. — 4 Φ 25 p^r m. = 4 bars 25 mm. dia. per metre.

Fig. 33. — Arched railway bridge 19 m (62 ft. 4 in.) span. (Swedish State Railways).

railway bridge crossing the river Frövian (fig. 33), a bridge of 19 m. (62 ft. 4 in.) span in which the granite abutments of the old metal bridge have been retained.

When the subsoil is not very good the Swedish State railways have frequently adopted the hinged arch. In this case the hinged-joints have often been only temporary because they have later been embedded in the concrete after the arch had settled. As an instance one may quote the railway bridge of 20 m. (65 ft. 7 in.) span over the river Fjällan; it is fitted with three temporary hinges of which that at the crown is given in figure 34. In other cases bridges have been constructed with three hinges properly so-called, as shown in the bridge over the Sävean (figs. 35 and 36) where the hinges are formed of rolled sections and also in the bridge over the Lundvägen at Malmo (fig. 37) in which the hinges are made of steel.

The most important railway bridge constructed in reinforced concrete in Scandinavia is that of the normal gauge railway constructed by the Swedish State Railways in the years 1917-1919 over the « Ore älv » (Swedish Northern Railway : Stockholm-Haparanda). This bridge is illustrated in figure 38. The main span is constructed of reinforced concrete as an arch with three steel hinge-joints. The span of the arch is 90 m. 7 (297 ft. 7 in.) and the versed sine of the intrados is 29 m. (95 ft. 2 in.). The width of the bridge at the top is 5 m. 22 (17 ft. 1 1/2 in.) and widens at the base to 7 m. 45 (24 ft. 5 1/4 in.). The arch is made of concrete in the proportions 1 : 3 : 3 and reinforced with about 0.1 per cent of round bar; near the hinged-joints, however, a concrete mixture of 1 : 1.5 : 2.5 was used; here the concrete reinforcement is also hooped. The platform of the railway consists of a structure of straight continuous girders of reinforced concrete supported every 9 m. (29 ft. 6 in.). On the one side of the central arch this is connected to the railway track by three small arches of 16 m. 2 (53 ft. 2 in.) span; on the other side, on which the sub-soil is bad, and where, for this reason, the central arch is carried on piled foundations (see fig. 38) it is only connected by a single arch of 32 m. 5 (106 ft. 7 1/2 in.) with three hinged-joints. All the side arches are made of concrete in the proportions 1 : 3 : 4; the piers in the proportion 1 : 5 : 7. The maximum permissible stresses on the large arch — subjected to a load corresponding to a locomotive axle carrying 20 t. and running at 100 km. (62.1 miles) per hour — are for concrete 55 kgr. 8 per cm^2 and for iron 785 kgr. per cm^2 (794 and 11 165 lb. per square inch).

The dimensions of the cross-section and of the iron embedded in it may be seen moreover in figure 39 which also shows the hinged-joint at the top of a large arch. Figure 40 gives a view of the bridge in process of construction. The cost of construction of the bridge amounted to about 1 400 000 kroner, of which about 526 000 kroner were for the large arch.

It is only in a very few cases that the Swedish State Railways have built railway bridges of square form. We may however refer to figures 35 and 36 which show this form of construction built to lengthen the arched bridge over the Sävean, which we have mentioned, and with which it has two common abutments. The thickness of the platform is 80 cm. (2 ft. 7 1/2 in.) and the span 6 m. (20 feet).

Railway bridges with curved girders, of reinforced concrete have not been used in Denmark, except for the bridge on the

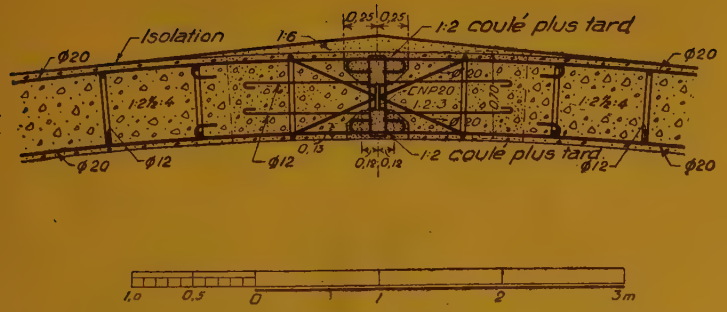


Fig. 34. — Detail of temporary top hinged-joint in arched railway bridge (Swedish State Railways).

Explanation of French terms: Isolation = Protective covering. — Coulé plus tard = Moulded at a later date.

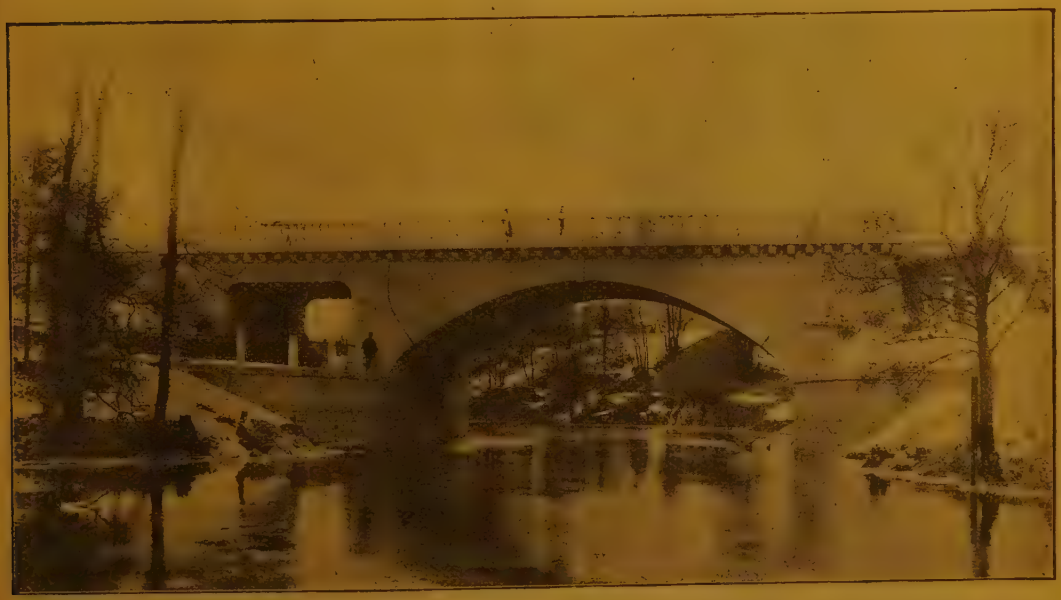


Fig. 35. — Railway bridge; structure of frame form in reinforced concrete and arch with three hinged-joints (Swedish State Railways).

Longitudinal section. Front elevation.

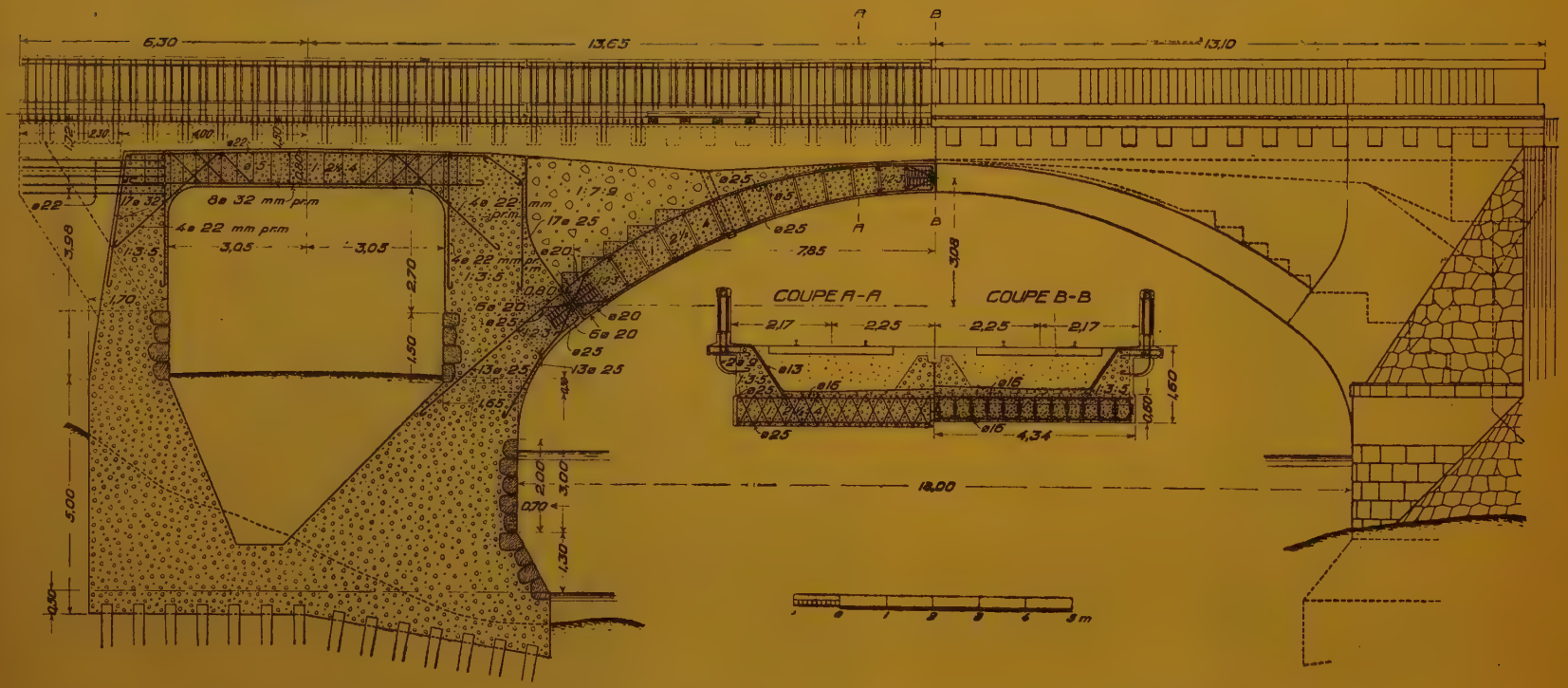


Fig. 36. – Railway bridge structure of frame form in reinforced concrete and arch with three hinged-joints (Swedish State Railways).

Explanation of French terms : Coupe = Section. — 8 ϕ 32 m/m. p^r m. = 8 bars 32 m/m. dia. per metre. — 4 ϕ 22 m/m. p^r m. = 4 bars 22 m/m. dia. per metre.

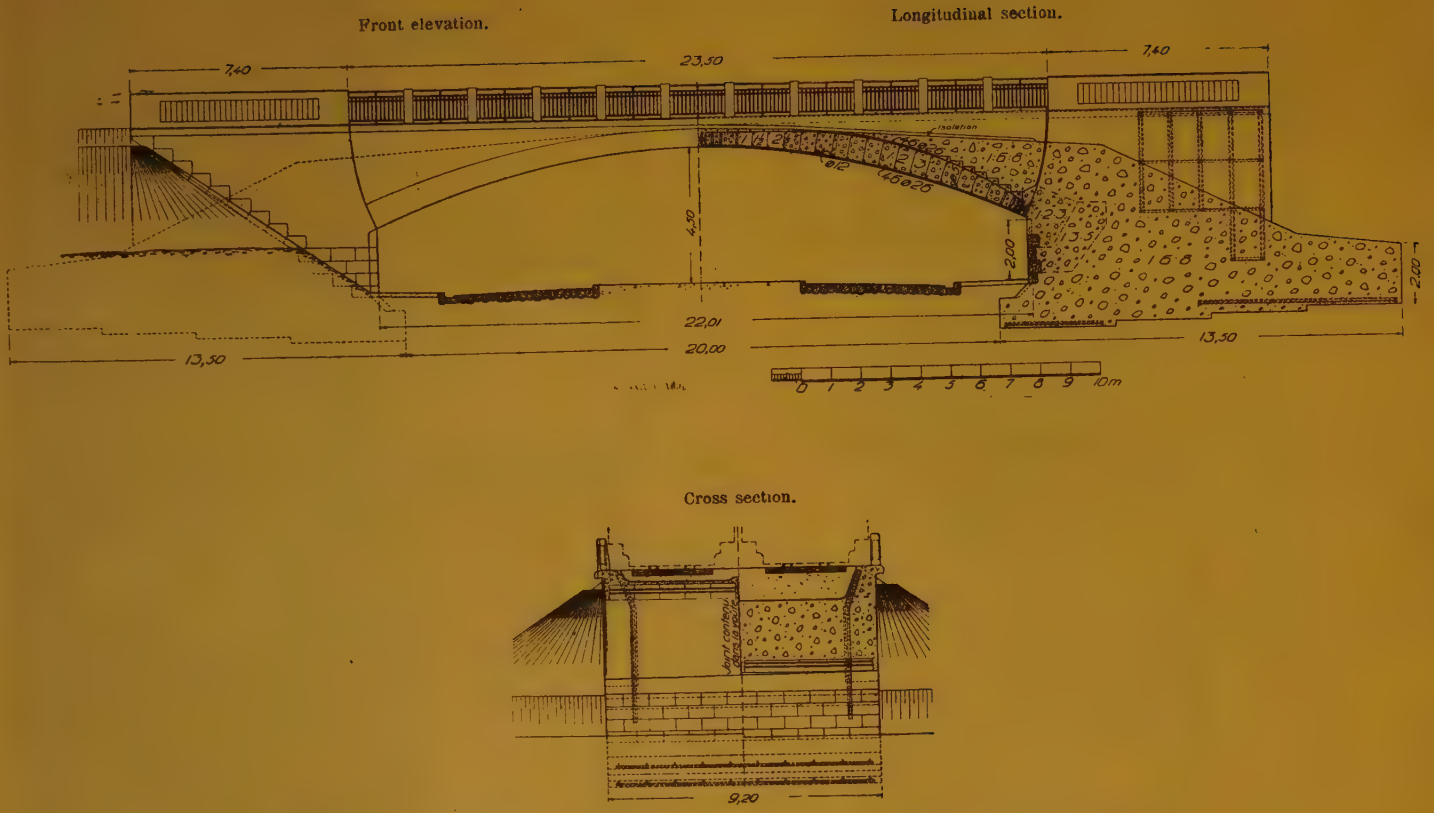


Fig. 37. — Railway bridge at Malmö; arch with three hinged-joints (Swedish State Railways).

Fig. 38. — Railway bridge over the Öre älv (Swedish State Railways).

Explanation of French terms : Portée libre = Clear span. — Portée théorique = Theoretical span.

Longitudinal section.

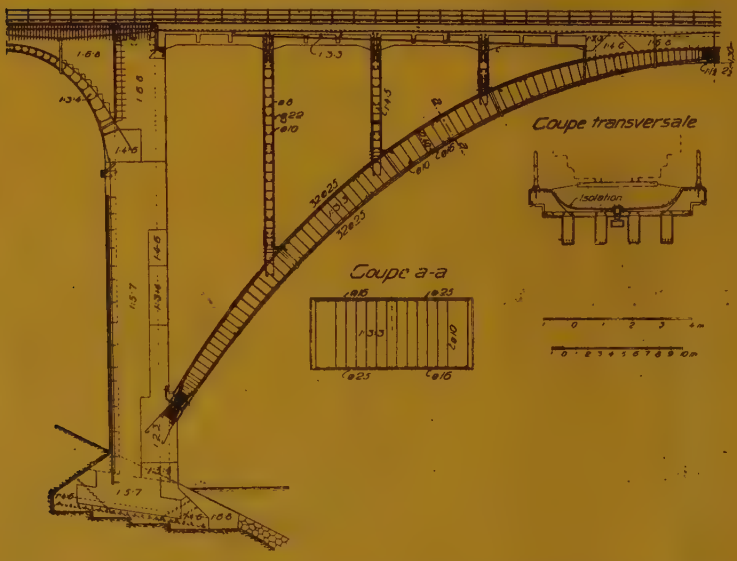


Fig. 39. — Railway bridge over the Öre älv (detail) (Swedish State Railways).

[*Explanation of French terms :* Coupe transversale = Cross-section. — Coupe *a-a* = Section on *a-a*.

Fig. 40. — Railway bridge over the Öre älv (during construction) (Swedish State Railways).

Fig. 41. — Railway bridge with bowstring girders (Danish State Railways).

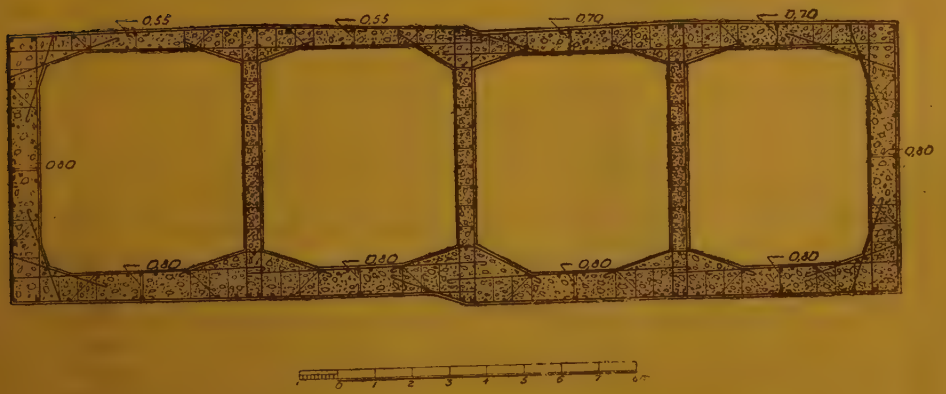


Fig. 42. — Four-track tunnel in Christiania (Norwegian State Railways).

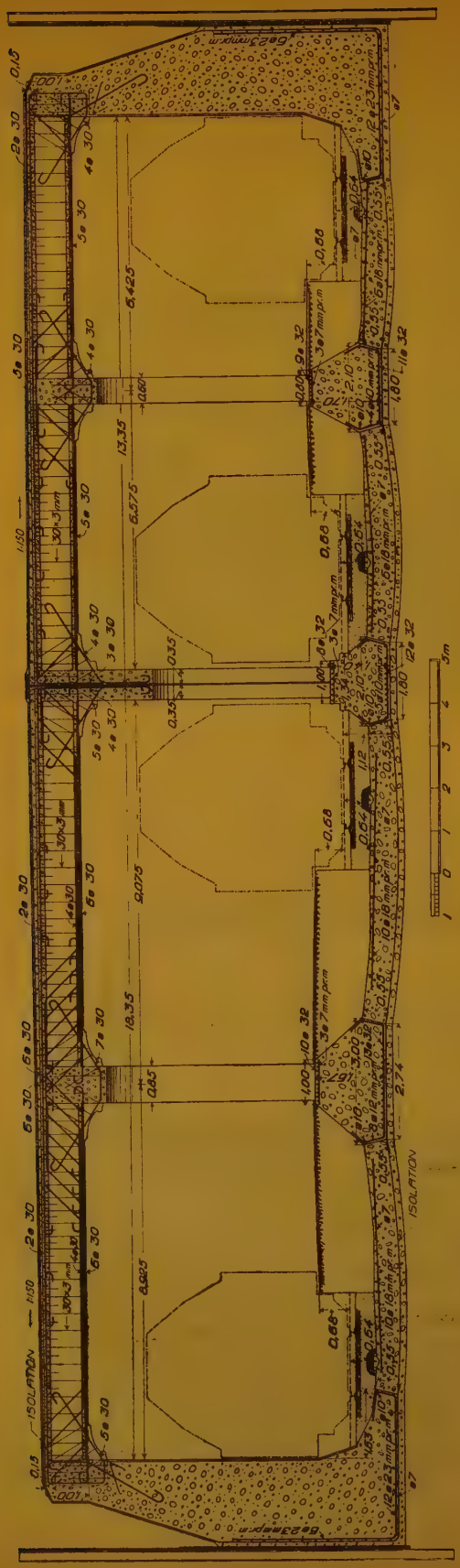


Fig. 43. — Four-track tunnel in Copenhagen (Danish State Railways).

line running to the port at Odense. This bridge which is shown in figure 41 has three spans each of 22.25 metres (73 feet); the skew is 1 : 2. The arched trusses are not stayed to each other at the top.

All the railway bridges which have been mentioned above, have been constructed in such manner that the ballasting is continued on the bridge. In one case only, have the Danish State railways constructed a temporary railway bridge, in which the sleepers are carried direct on a floor of reinforced concrete.

In Norway, at least as far as we are aware, no railway bridges have been constructed entirely of concrete or of reinforced concrete, but on the other hand a large number of small bridges have been constructed with rolled sections embedded in the concrete.

d) *Tunnels and other works.*

Tunnels of concrete and reinforced concrete are to be found in the three Scandinavian countries.

The Norwegian State Railways have constructed a tunnel in ordinary concrete at Trondhjem for a single line and a similar one near Selsbak, the bottom of which is however made of reinforced concrete. The same railways have also two double-track tunnels about 200 m. (219 yards) in length in course of construction at the Christiania Eastern Station. These are entirely constructed in reinforced concrete; for a portion of the length the two tunnels are merged into one; figure 42 shows a cross-section taken in the four-track portion of the tunnel.

In Copenhagen the Danish State Railways have constructed a long tunnel about 1 500 m. (1 640 yards) in length to connect the Central station with the Eastern station by four tracks. The central third of this underground railway is occupied

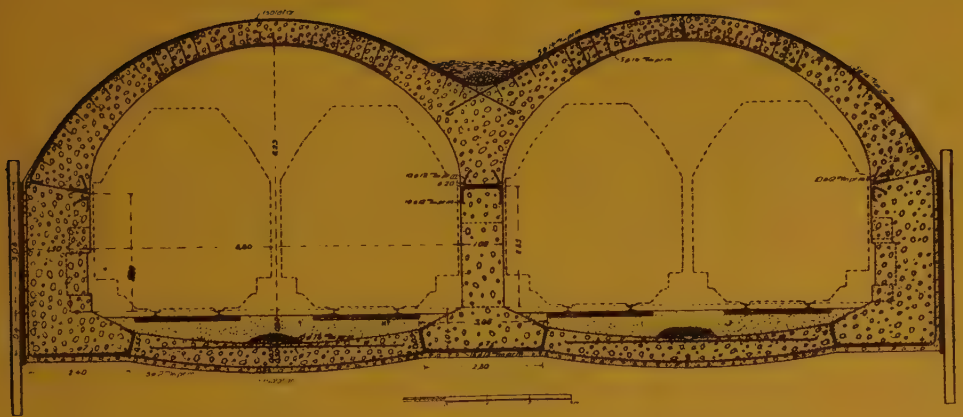


Fig. 44. — Four-track tunnel in Copenhagen (Danish State Railways).

Explanation of the French term : Isolation = Protective covering.

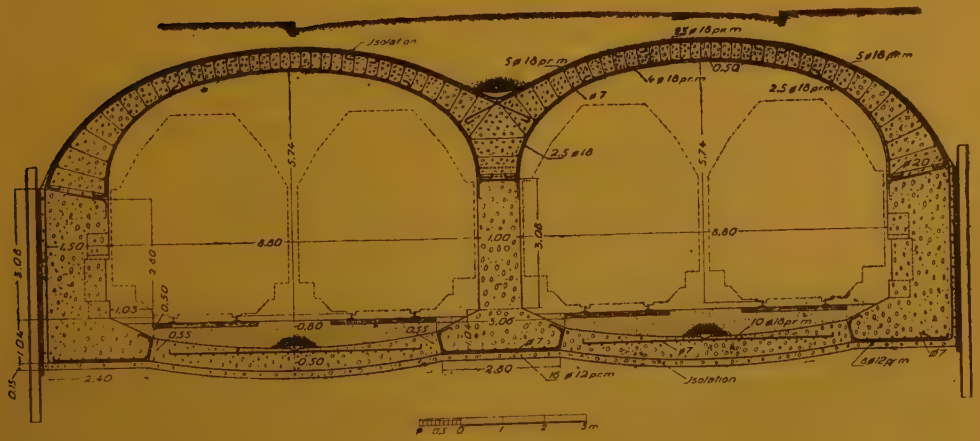


Fig. 45. — Four-track tunnel in Copenhagen (Danish State Railways).

by a station about 500 m. (547 yards) in length; this station has two platforms from which the necessary staircases communicate with the roadway above. At each end of this station the tunnel continues for a length of about 500 m. As the tunnels are situated at different depths in relation to the roadway above, they have been constructed of different sections. Figures 43, 44 and 45 show three different cross-sections of the underground railway. One of these, as will be seen, is taken through the passenger station, which is covered with a flat roof The whole of the underground railway is protected externally by a covering of bitumen (callendrite). The tunnel has been open to traffic since 1917.

Among other tunnels constructed in Denmark may be mentioned a four-track tunnel in course of construction at Aarhus which will pass underneath the station at this spot. It is intended to construct about 75 m. (246 feet) of this tunnel as an ordinary concrete arch, while for a length of 120 m. (393 ft. 8 in.) the tunnel will be carried out as a straight-girder structure of reinforced concrete as shown in figure 46. The figure shows that the arrangement of the side walls is somewhat similar to that mentioned below in chapter VII (fig. 59); but the pressure of the ground acting in the opposite direction has required the construction of a large number of refuges which are necessary in this instance.

Lining tunnels with reinforced concrete, has been adopted in some cases in Sweden where a tunnel has been carried through a mountain consisting of soft rock.

In the three Scandinavian countries a large number of *reinforced concrete subways at stations connecting one platform with another* have been constructed. The Danish State Railways generally use ordinary concrete for the sides and bottom of such structures while the roof consists of rolled sections encased in concrete. In such cases the Norwegian Railways have adopted a closed-frame form of construction. The Swedish railways have also used this type in many cases. Moreover in Sweden some of these subways have been constructed with sides of ordinary concrete and roofs of reinforced concrete; in other cases the sides and the bottom have been of reinforced concrete and the roof has been constructed of rolled sections with slabs of concrete between them; in this case the sleepers are laid direct on the iron girders.

With regard to the question of *the use of reinforced concrete for certain portions of important structures* we may mention that balustrades or railings have been made of reinforced concrete as will be seen below, in chapter VII (fig. 68).

The Danish State Railways have also in one instance cased the lower portions of a railway bridge in reinforced concrete in consequence of the difficulty that existed in this case of preserving the bridge by means of paint.

CHAPTER VI.

Buildings and structures of this class.

In the Scandinavian countries reinforced concrete is largely used for *buildings,* in the construction of floors, of pillars and columns, of roofs and other works of this class. It is also not uncommon to see buildings constructed entirely of concrete and of reinforced concrete.

The ordinary floors consisting of reinforced concrete girders with intermediate slabs of reinforced concrete (Hennebique

system) are to be found everywhere, particularly in the Scandinavian countries; and, in all new constructions of works of magnitude (in any case as far os Denmark is concerned) they are used more frequently than wood or iron floors. We

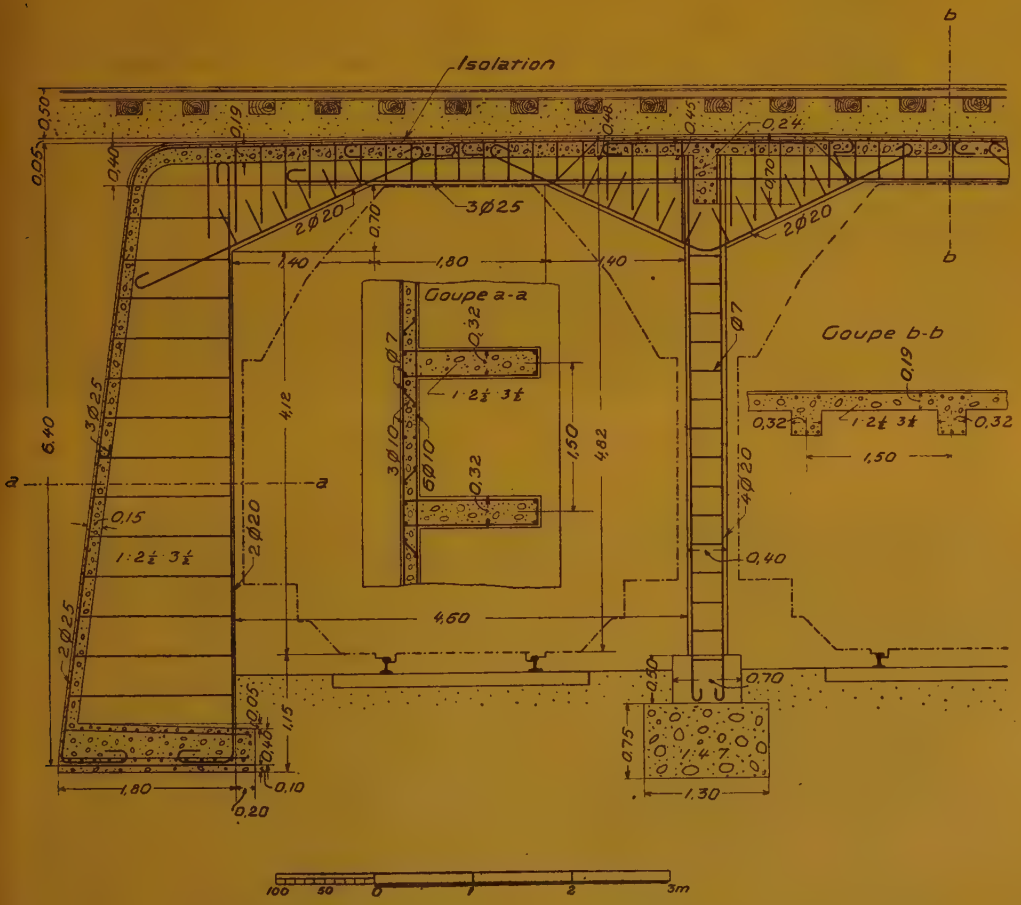


Fig. 46. — Two-track tunnel in Aarhus (Danish State Railways).

Explanation of French term : Coupe = Section.

shall not deal with these reinforced concrete structures which we consider to be of a well-known type.

With regard to new forms of flooring in reinforced concrete, for example, the floors constructed on the « Paddehat » system, it is to be noted that this construction is fairly often used outside railway practice, but (according to the information which has reached us) it has not yet been so used by the Scandinavian railways. The « Paddehat » system in par-

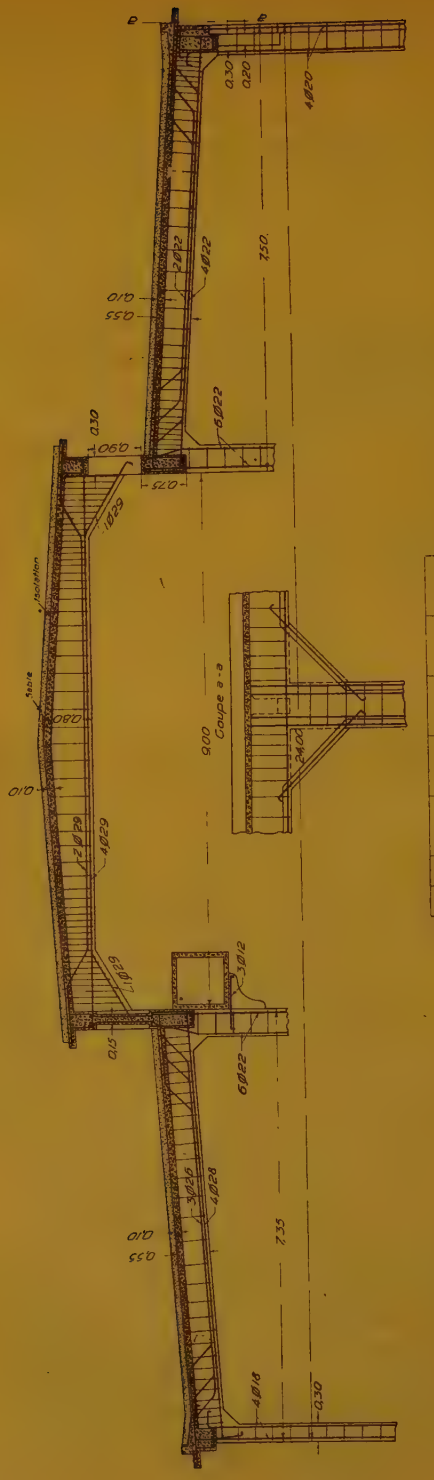


Fig. 47. — Locomotive-shed roof at Upsala (Swedish State Railways).
Explanation of French terms: Coupe a-a. = Section on a-a. — Isolation = Protective covering. — Sable = Sand.

ticular is used when it is a question of the construction or depots or generally of covering large spaces.

As in the case of floors, roofs of reinforced concrete are also much used in the northern countries. If the floors in a building, are of reinforced concrete, the roof will very often also be constructed of the same material; moreover, if conditions are favourable, concrete is used in many instances in the construction of the roofs of locomotive sheds, workshops, goods sheds and structures of this class.

It can scarcely be said that there is a normal type of roof as the forms of construction adopted are most varied; flat roofs are as common as saw-tooth roofs or arched roofs, the latter supported by arched ribs with or without tie-bars.

As an example of a roof of fairly large dimensions we may mention that of a workshop (the smiths' shop of the Swedish State Railway at Malmö); in this case the roof is supported by arched ribs with tie-bars (span : 20 m. [65 ft. 6 in.], versed sine of the soffit about 3 m. [10 feet]). We may also call attention to the roof of the locomotive sheds at Upsala constructed of reinforced concrete (Swedish Railways); this roof is shown in cross-section in figure 47.

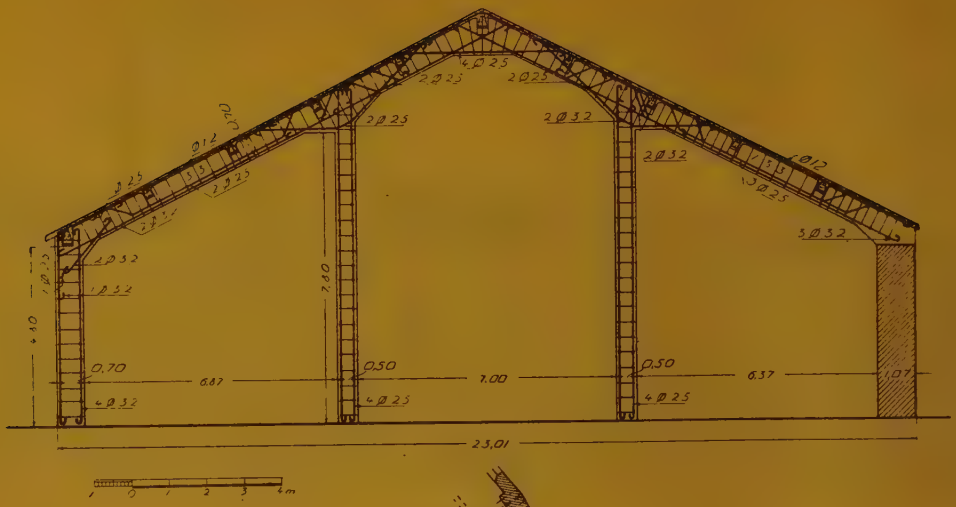
Reinforced concrete has found wide application in the large workshops of the Danish State Railways at Aarhus (Jutland); two types of roof have been used in this case, flat saw-tooth arrangement *(Shedtoituser)* and curved. We may mention, for example, the roof of the locomotive repair shops, covering an area of about 20×50 m. (65 ft. 6 in.×163 ft. 9 in.) which is covered by a saw tooth roof of eight spans at this place.

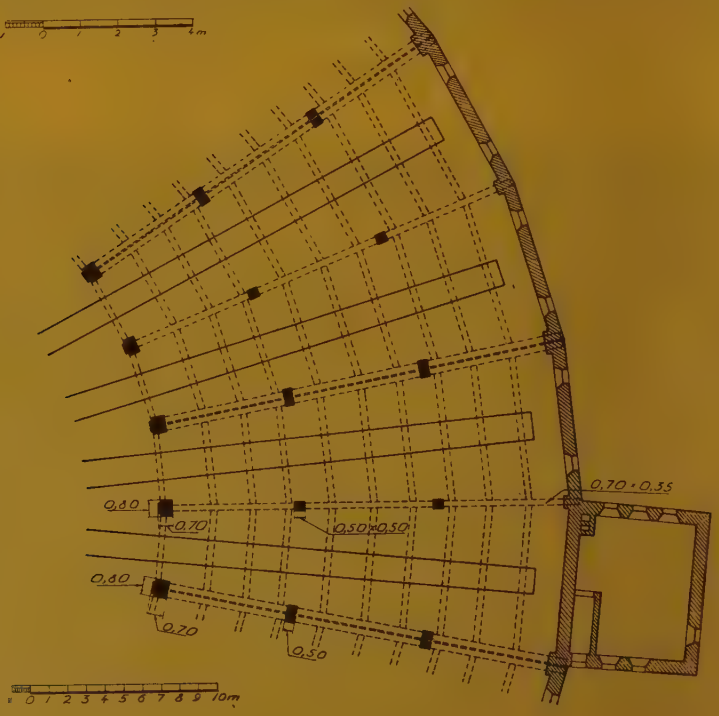
Among buildings constructed entirely of concrete the locomotive sheds of Järva and at Norrköping in Sweden may be

Fig. 48. — Locomotive-shed at Järva (Swedish State Railways).

Fig. 49. — Locomotive-shed at Järva (Swedish State Railways).

Cross-section.





Plan.

Fig. 50. — Locomotive-shed at Aal Station (Norwegian State Railways).

mentioned; the first is shown in figs. 48 and 49 giving external and internal views. Structures consisting almost entirely of reinforced concrete are also found in Norway, for example the locomotive sheds at the Aal station on the Bergen line (Norwegian State Railways). The shed is of circular form and is shown in plan and cross-section in figure 50.

Locomotive sheds are however only

Fig. 51. — Round house type of locomotive-shed near Häsleholm (Swedish State Railways).

very rarely constructed entirely of reinforced concrete. Generally it is the roofs and the front wall that are constructed of reinforced concrete, while the back wall and the sides are of ordinary brickwork; we may refer for example to figure 51 which shows a Swedish round locomotive shed now being constructed near Häsleholm.

As in the case of locomotive sheds there are also shops constructed almost entirely of reinforced concrete. Several examples of this type are to be found in the large workshops at Malmö (Swedish State Railways).

The *station platform roofs, properly so-called,* are very rarely constructed of reinforced concrete; we can, however, mention a fairly large arch of concrete 37 m. (121 ft. 5 in.) span, which the Norwegian State Railways have built at the new

Bergen Station. This arch is at the end of the iron arches forming the hall and has a cross-section at the top 65×120 cm. (2 ft. 1 5/8 in. × 3 ft. 11 1/4 in.) and the abutments 65×240 cm. (2 ft. 1 5/8 in. ×7 ft. 10 1/2 in). The reinforcement consists of four angle-iron bars connected by round bars.

Water-towers and tanks of reinforced concrete have been fairly largely adopted in the Scandinavian countries.

Water-towers have been constructed of which the building itself as well as the tank are of reinforced concrete; other water towers have been built in which the tank and the girders carrying the structure alone (or the supports under the tank) are of reinforced concrete.

In Sweden the State Railways have up to the present time constructed about ten water-towers, all of reinforced concrete, with tanks capable of holding up to 200 tons of water.

Figure 52 shows a water-tower near Eslöv (Swedish State Railways) constructed in 1913; the skeleton supporting the structure consists of columns of reinforced concrete which are connected to one another by horizontal curved girders while the space between the girders is filled with ordinary brickwork. Figure 53 shows another tank constructed by the Swedish State Railways in 1918-1919 near Bollnäss; this tank is capable of containing 200 m^3 (200 tons) of water.

Figure 54 shows a tank constructed by the Danish State Railways at Gjedser; the tank and its supports alone are of reinforced concrete, whereas the rest of the structure (the tower) is of ordinary brickwork.

In Norway a tank has also been constructed in reinforced concrete, set in a brickwork tower at the Trondhjem works (Norwegian State Railways). This tank has a capacity of about 100 tons.

In Scandinavia all the tanks are of circular form which is the natural shape if account is taken of the forces to which the tank is subjected. This form is at the same time economical from the point of view of the quantity of material required and it is always considered to be the least liable to leakage when in use.

The proportion of the concrete in various tanks differs (except in the case of the Trondhjem tank, quoted above, which is made of a 1 : 2 : 1 mixture) between 1 : 2 : 3 and 1 : 2.5 : 3; the mixture 1 : 2.5 : 2.5 is also often used. With these mixtures (particularly the 1 : 2 : 3 mixture), it is thought that the tanks are practically water tight, but the mixture is not thoroughly satisfactory where it is necessary to obtain complete impermeability. The Swedish State Railways say that at one time the internal walls of the reservoirs were finished with a « Ceresit » mortar and afterwards with « Kesslers Fluat ». In the new tanks the internal walls are rubbed down (with a piece of steel) and are afterwards coated with Innertol or with Kesslers Fluat.

In Norway this polishing operation is also often used as well as the coating of « Inertol », but in Denmark a coating with Ceresit is generally used.

If the concrete is rich and is carefully mixed and placed, in many cases, there is no need for a special coating, or in any case it is only necessary to cover the wall with neat cement in order to obtain perfect impermeability.

CHAPTER VII.

Various applications of concrete.

Sleepers. — Attempts have been made to use reinforced concrete sleepers in

Fig. 52. — Water-tower at Eslöv (Swedish State Railways).

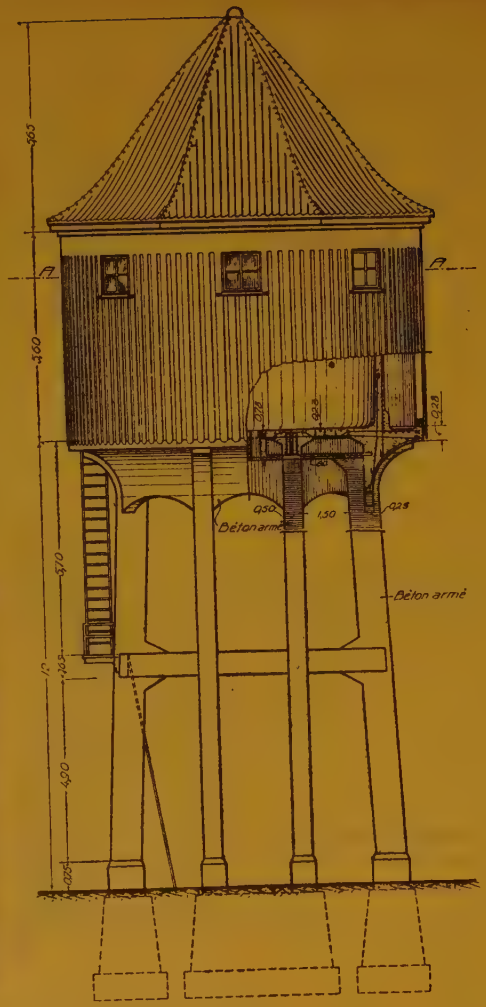


Fig. 53. — Water-tower at Bollnäs (Swedish State Railways).

Explanation of French terms ; Béton armé = Reinforced concrete.

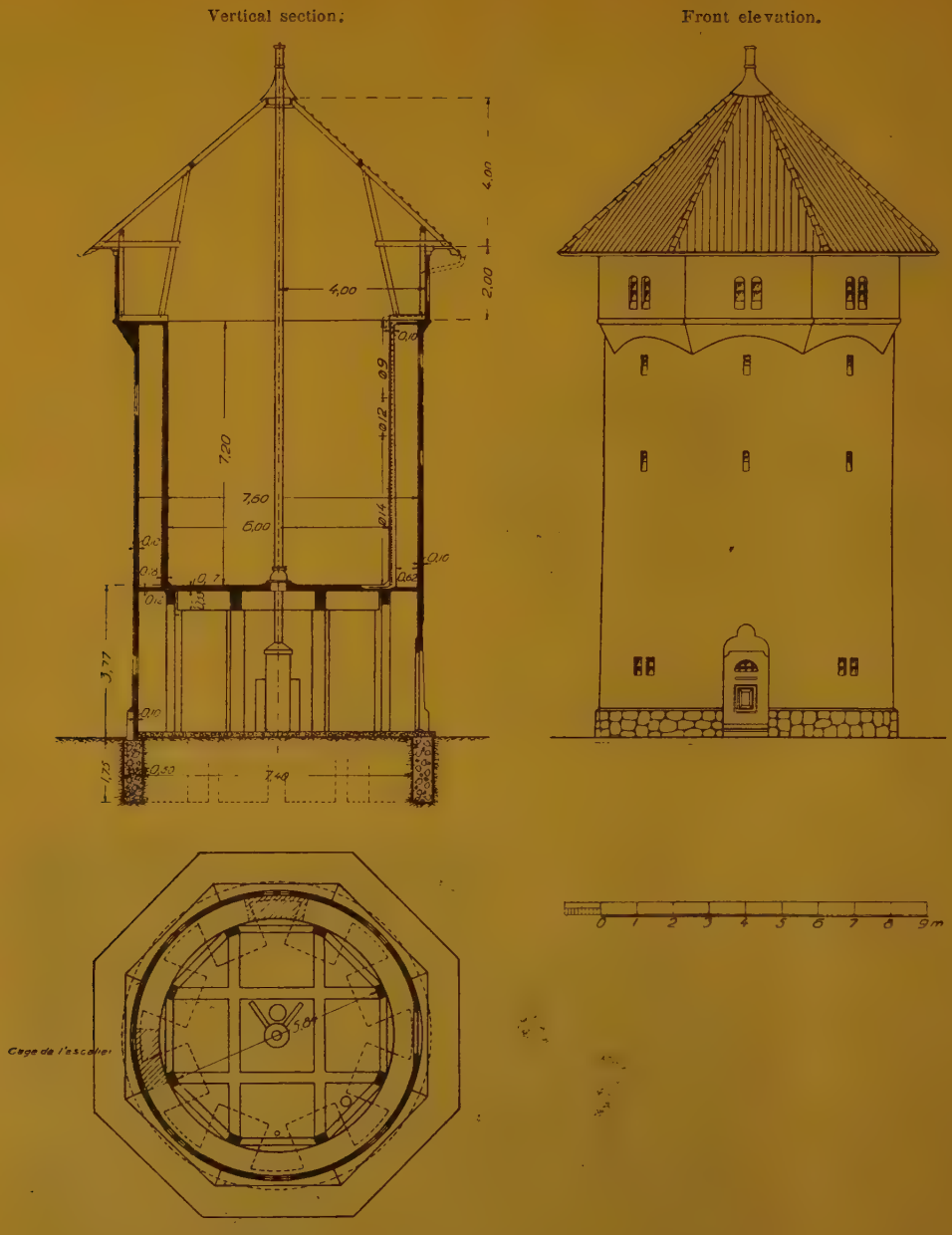


Fig. 54. — Water tower at Gjedser (Danish State Railways).

Explanation of the French terms : Cage de l'escalier = Staircase well.

Denmark and also in Sweden. Trials of this kind have not yet been undertaken in Norway, but, according to information which has reached us, it is intended to make trials very shortly and the matter is already under consideration.

Experiments made in Denmark date from 1905, but have not given good results. Two different types of sleepers have been tried one of which (fig. 55) showed itself superior. The Danish railways laid about 2 000 concrete sleepers on trial on the main lines; but after a few years it was necessary to renew 50 per cent of those on account of the destruction of the concrete arising from the shocks produced by the passage of the trains. Experiments have also shown that the wood packing placed under the rails is liable to decay very readily.

In Sweden also the experiments made with concrete sleepers have not given good results. They date from 1911 and were made by the Swedish State Railways.

The first Swedish experimental sleepers, shown in figure 56, which were supplied by a private cement company soon showed that they were much too weak. The reinforcement was too thin and cracks appeared at the centre of the sleepers after they had only been in use a few months; the wooden packing 5 mm. (3/16 inch) in thickness, placed between the sleeper and the bottom of the rail, moreover gave rise to a great deal of difficulty, because it dried in dry weather and the screwspikes required to be tightened, and this could often only be done with difficulty.

In 1913 one hundred sleepers known as « Asbeston », made by the « Zementbaugesellschaft Rud. Wolle », Leipzig, were tried. These sleepers again were not successful, for, after being only a short time in use the rails sank into the sleepers, and after only two years work the rails had sunk down in many places until they bore directly on the iron reinforcements, as is shown in figure 57.

Finally, in 1917, fifty Asbeston sleepers (fig. 58) were purchased from the « Asbeston Gesellschaft » of Berlin, with bearing-plates and screwspikes, but notwithstanding the use of bearing-plates, experience showed that the sleepers did not meet the requirements necessary for railway work.

It follows from the preceding that the experiments with reinforced concrete sleepers, made in Scandinavian countries up to the present, have proved failures; but, on the other hand, it should be noted that these experiments have not up to the present been numerous or complete enough to enable a general conclusion to be drawn from them. They show however that it is difficult te obtain sleepers of reinforced concrete at a reasonable price which are sufficiently strong, concrete appears unsuited to stand the violent shocks and vibration to which sleepers are exposed, and up to the present no satisfactory method has been found of securing the rails to the sleepers. We should also add that their weight makes carriage heavy and handling very inconvenient. In the existing state of affairs we think that we can state that, up to the present, concrete sleepers have not been able to compete successfully with wooden sleepers; the latter, under normal conditions and if they are of good quality and creosoted, have a life of twenty to twenty-five years and often even more.

Telegraph and telephone poles and signal posts, made of concrete have not found any use on the railways of the Scandinavian countries.

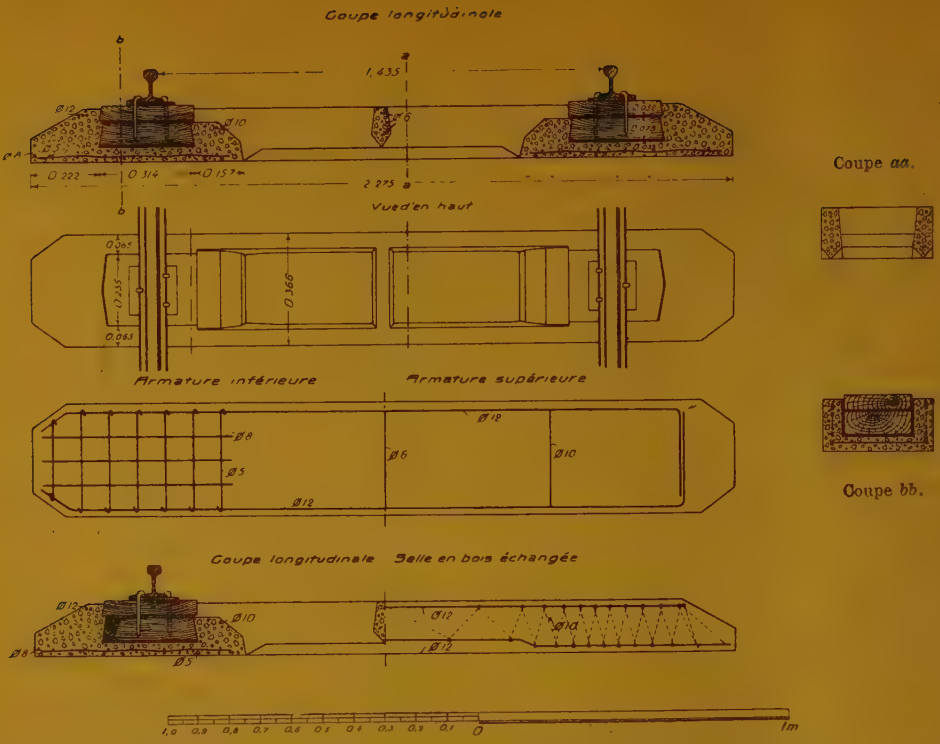


Fig. 55. — Old form of reinforced-concrete sleeper (Danish State Railways).

Explanation of French terms : Coupe longitudinale = Longitudinal section. — Vue d'en haut = Top plan. — Armature inférieure = Lower reinforcement. — Armature supérieure = Upper reinforcement. — Selle en bois échangée = Wooden packing piece renewed. — Coupe = Section on *aa* — *bb*.

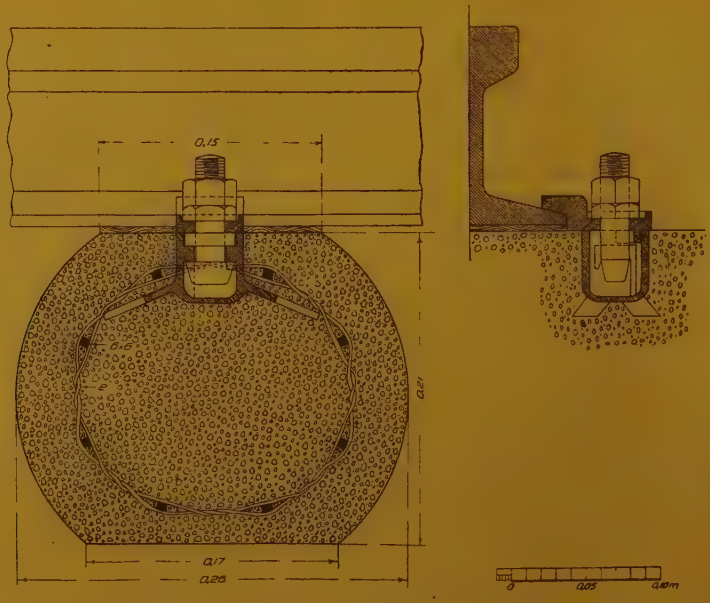


Fig. 56. — Old form of reinforced-concrete sleeper (Swedish State Railways).

Fig. 57. — Reinforced-concrete sleeper destroyed after two years work (Swedish State Railways).

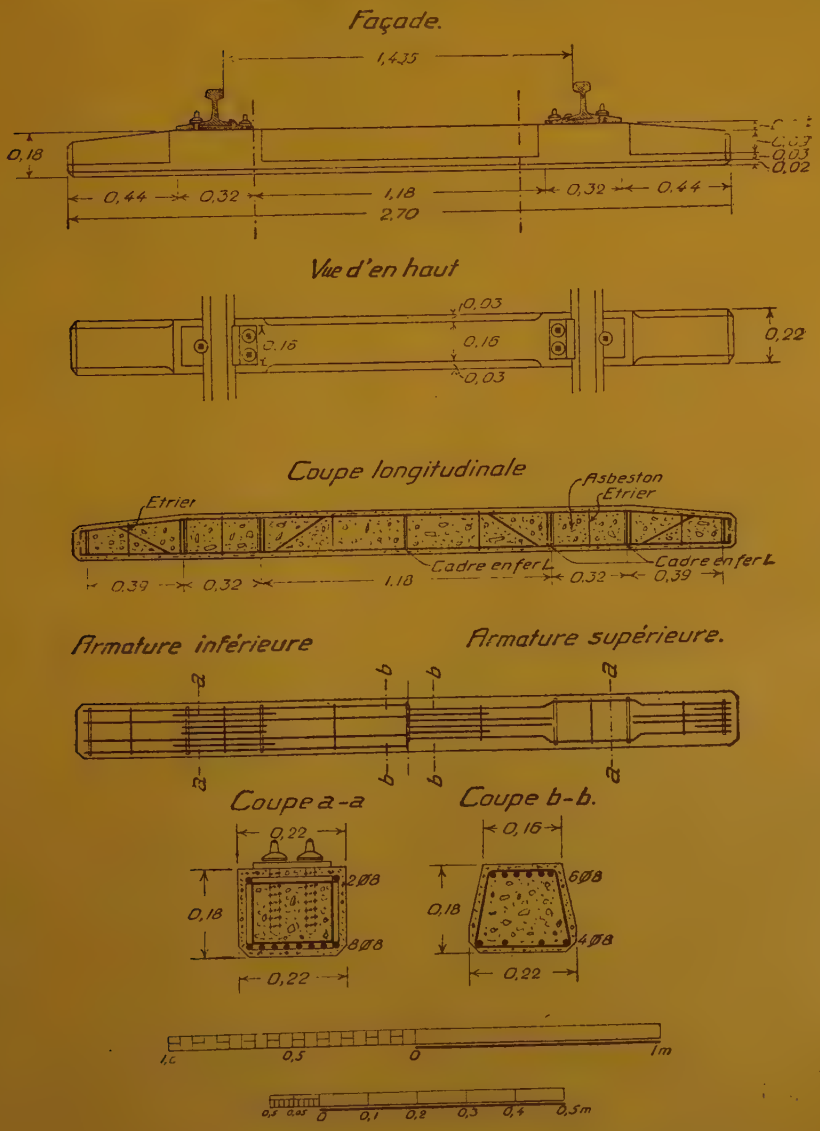


Fig. 58. — Reinforced-concrete sleeper, new pattern (Asbeston).

Explanation of French terms : Façade = Front elevation. — Vue d'en haut = Plan. — Coupe longitudinale = Longitudinal section. — Coupe = Section. — Etrier = Stirrup. — Asbeston = Asbeton. — Cadre en fer = Angle-iron frame. — Armature inférieure = Lower reinforcement. — Armature supérieure = Upper reinforcement.

Retaining and protecting walls of concrete and of reinforced concrete are very frequently used in the Northern countries and the material is well adapted to this use.

In general all low (or short) retaining walls are built as solid walls made of ordinary concrete in the proportions 1 : 4 : 7, but, on the other hand, if the wall is high or of considerable length reinforced concrete is almost always used.

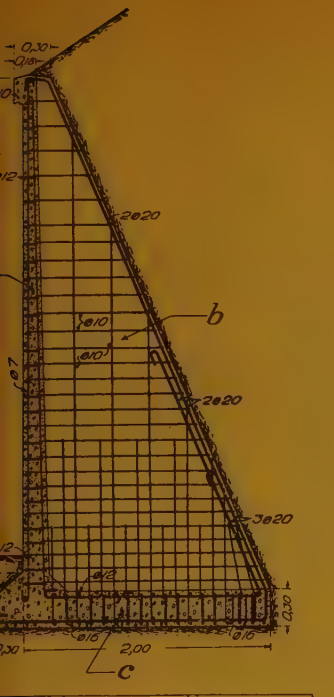
The most general form of construction for retaining and protecting walls of reinforced concrete is that shown in figure 59; in this the retaining wall consists of a vertical screen of reinforced concrete *a*, which forms the front of the wall, strengtened by triangular buttresses *b* at regular intervals, for exemple every 1 m. 5 to 2 m. 5 (4 ft. 11 in. to 8 ft. 2 3/8 in.), fixed to the horizontal toe of the wall. This construction, amongst others, has been used by the Danish State Railways for the retaining walls of four elevated railways running from the Copenhagen Eastern Station northwards. The walls in question have a total length of about 900 m. (2 950 feet). They were constructed in 1908-1909 and have stood up in a thoroughly satisfactory manner.

In certain cases buttresses have not been used and protecting walls have been built when the wall has not been very high (less than 2.5 m. [8 ft. 2 3/8 in.]) as shown in figure 60. This form of construction is however not satisfactory; under heavy loads it is too weak at the top of the angle where the iron rods are bent over. It may also be said that the use of bends is a source of weakness at points at which the direction of the bars changes, except when the bends are of large diameter; this can easily be proved by theoretical investigation and is confirmed by practice.

Simple retaining walls, consisting of reinforced concrete slabs laid between short lengths of rails, serving as retaining walls for slopes, embankments, etc., have been carried out at various places and are only mentioned here for the sake of completeness.

In Denmark, amongst retaining walls that have been newly constructed, we may mention the retaining walls of the Copenhagen underground railway. These walls, shown in figure 61, have a total length of about 900 m. (2 950 ft.). They consist of a series of massive pillars, 7 m. (23 ft.) centre to centre, between which concrete arches haves been thrown to form a second wall at the back of the retaining wall, while the space enclosed between the piers is covered by concrete arches on which the upper retaining wall is carried. The upper portion of these walls also forms the parapet of the footpath of the road behind. Figure 62 shows a normal cross-section of the wall from which its dimensions can be ascertained; the massive piers themselves are 2×2 m. 5 (6 ft. 6 3/4 in.×8 ft. 2 3/8 in.) in horizontal cross-section.

As the underground railway is visible from one of the busiest streets of the city considerable trouble has been taken to improve the appearance of the outside of the retaining walls. These are provided with a granite foundation stone at the bottom 0 m. 80 (2 ft. 7 1/2 in.) in height covered with a special coating which gives them a more agreeable and pleasing appearance. From the architectural point of view the arches are also an ornament as they break the monotony of the large surfaces. Moreover the recesses have the advantage of serving as refuges for the permanent way staff of the railway, in a place where refuges are greatly wanted, as the main line runs



9. — Reinforced-concrete retaining wall (Danish State Railways).

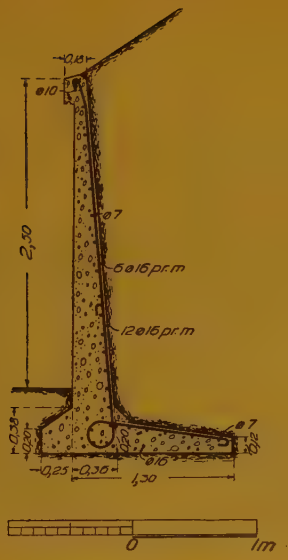


Fig. 60. — Small reinforced-concrete retaining wall (Danish State Railways).

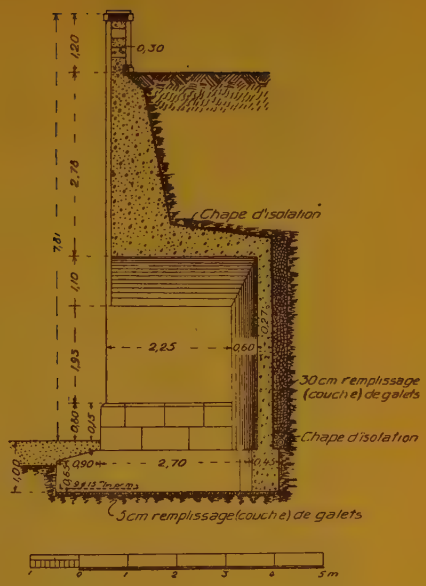


Fig. 62. — Vertical section through the retaining walls shown in figure 61 (Danish State Railways).

Explanation of French terms : Chape d'isolation = Protective covering. — 30 cm. remplissage (couche) de galets = 3 foot filling (layer) of pebbles.

Fig. 61. — Reinforced-concrete retaining walls in Copenhagen (Danish State Railways).

Fig. 63. — Paving of slope with concrete slabs (Danish State Railways).

Fig. 64. — Paving of slope with concrete slabs (Danish State Railways).

alongside the wall for a long distance having only the gauge clearance.

These walls were built in 1913-1914 and proved fairly economical.

Supporting the sides of ditches by concrete slabs is practised in some cases in Denmark. Figures 63 and 64, for example, show a form of construction in which the side of a bank is covered with reinforced concrete slabs. The slabs are 1 m. (3 ft. 3 3/8 in.) square (with the corners cut off) and are 8 cm. (3 1/8 inches) in thickness. The work is carried out as follows : on the inclined surface, consising of clay and having a slope of 2 to 1, holes 1 m. (3 ft. 3 3/8 in.) deep were sunk, after which pieces of rail were planted in them and bedded in concrete; the projecting ends of the rails were subsequently attached to the iron reinforcement bars of the four slabs meeting at the point to which they were fastened.

The protecting covering was constructed in 1910 and has stood well.

As another example of the protection of banks with concrete slabs one may mention the strengthening of a railway enbankment at Kolding fjord in Denmark. The bank in question was in the first instance covered with a stone glacis of a certain height, but it was later found that it was necessary to protect the slope to a still greater height. Instead of raising the glacis it was thought better to place a coating of concrete slabs 1 m.(3 ft. 3 3/8 in.) square above the stone glacis. This work was carried out in 1917 and so far has stood well.

Platform walls of reinforced concrete, have been very much used in the northern countries and they are now nearly always adopted for new structures. Figure 65 shows the type of platform walls most in use on the Danish State Railways for low and high platforms respectively. The edges are generally formed in sections 2 m. (6 ft. 6 3/4 in.) long and joined up on the site.

In many places the old pattern of platform wall is to be found in which the wall consists of vertical slabs of concrete retained by old rails every 2 m. (6 ft. 6 3/4 in.).

Figure 66 shows a type of platform wall used by the Norwegian Railways; as will be seen from the figure the platform wall consists of vertical slabs of reinforced concrete, 8 cm. (3 1/8 inches) in thickness and 2.5 m. (8 ft. 2 3/8 in.) in length placed between buttresses of reinforced concrete 0.5 m. (1 ft. 7 3/4 in.) wide which resemble in their form of construction the retaining wall shown in figure 59. As will be seen, the upper portion of the concrete at the edge of the platform is protected by an iron moulding.

Working and inspection pits are almost always constructed of reinforced concrete. Figure 67 shows a working pit of reinforced concrete, capable of being transported, constructed by the Danish State Railways in 1911. The pit is 12 m. (40 feet) long and is divided into four portions each 3 m. (10 feet) in length. The pit is in perfect condition and the fact that it was constructed in four sections has not led to any trouble. It was formed of concrete in the proportions 1 : 2 : 3.

Figure 5 shows a small working pit constructed by the Southern Fionian Railways (Denmark).

Amongst other uses for concrete and reinforced concrete on railways may be mentionned posts (uprights) for railings (fig. 68) fencing, culverts, etc.; chimneys

are also constructed of reinforced concrete in some places.

On the Danish State Railways transportable *foundations for cranes* have also been constructed in reinforced concrete; figures 69 and 70 show these transportable

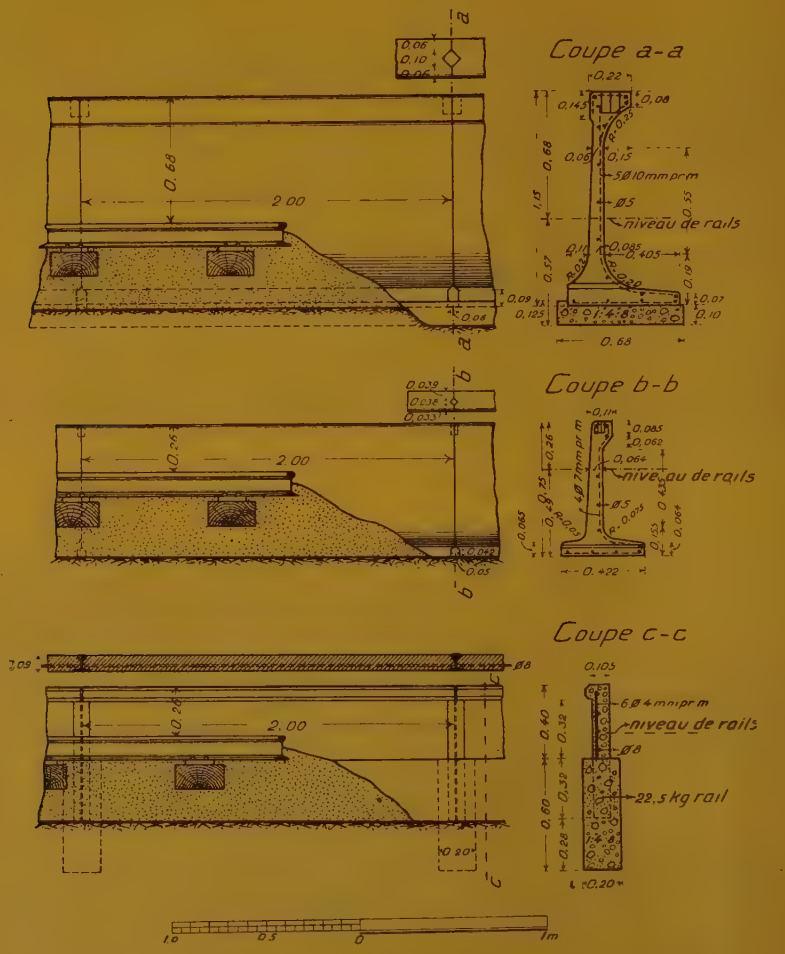


Fig. 65. — Various types of platform walls (Danish State Railway).

Explanation of French terms: Coupe = Section. — Niveau de rails = Rail level. — 5 ϕ 10 mm. p^r m. = 5 bars 10 mm. dia. per metre. — 6 ϕ 4 mm. p^r m. = 6 bars 4 mm. dia. per metre. — 22 kgr. 5 rail = Rail 45 lb. 4 per yard.

foundations of reinforced concrete respectively for cranes of 35 cwt. and 5.5 tons.

In conclusion we should note that the Swedish State Railways have made attempts to construct *snow-screens* in reinforced concrete.

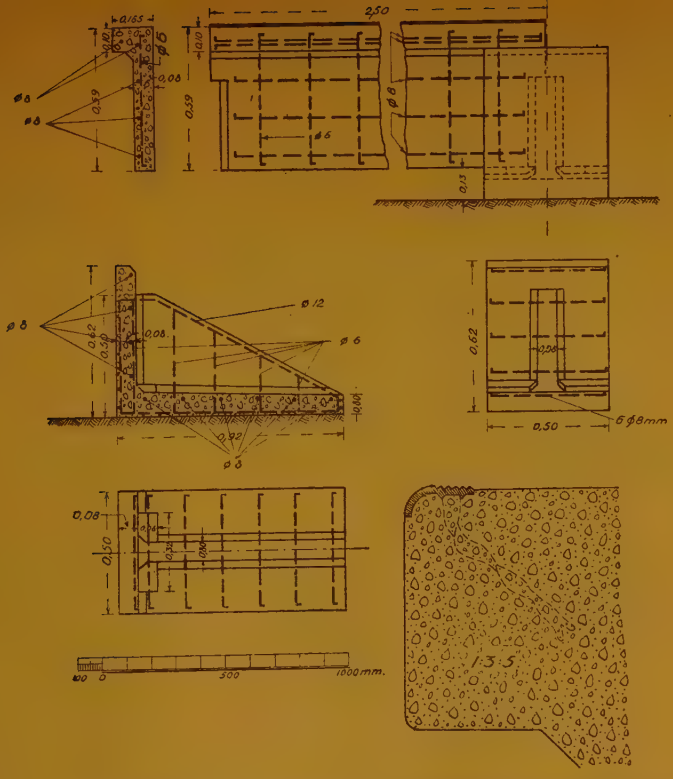


Fig. 66. — Norwegian type of platform wall (Norwegian State Railways).

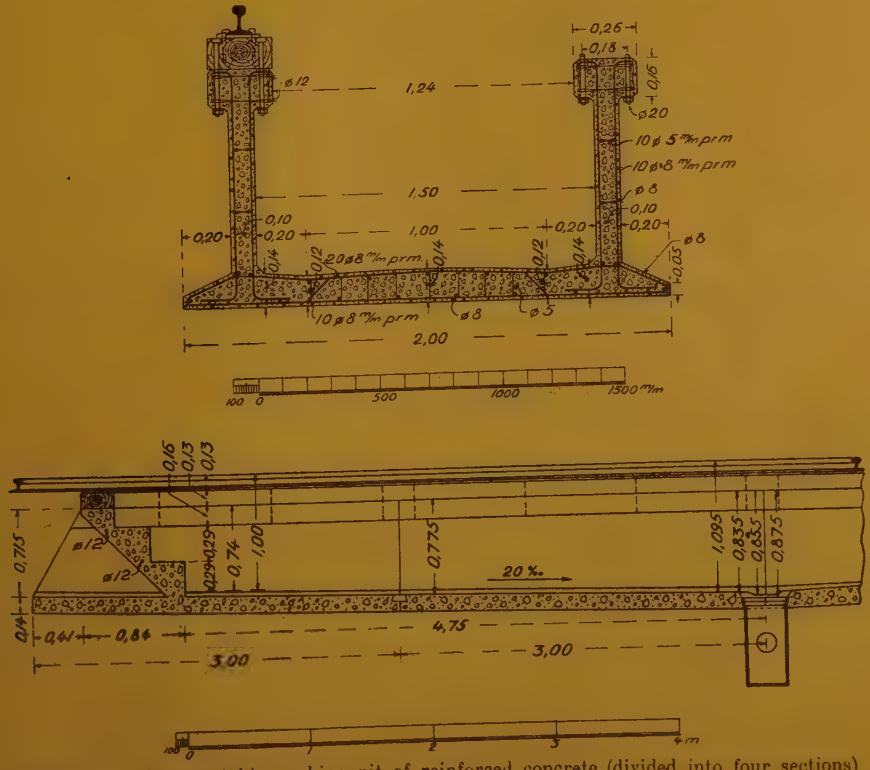


Fig. 67. — Transportable working pit of reinforced concrete (divided into four sections) (Danish State Railways).

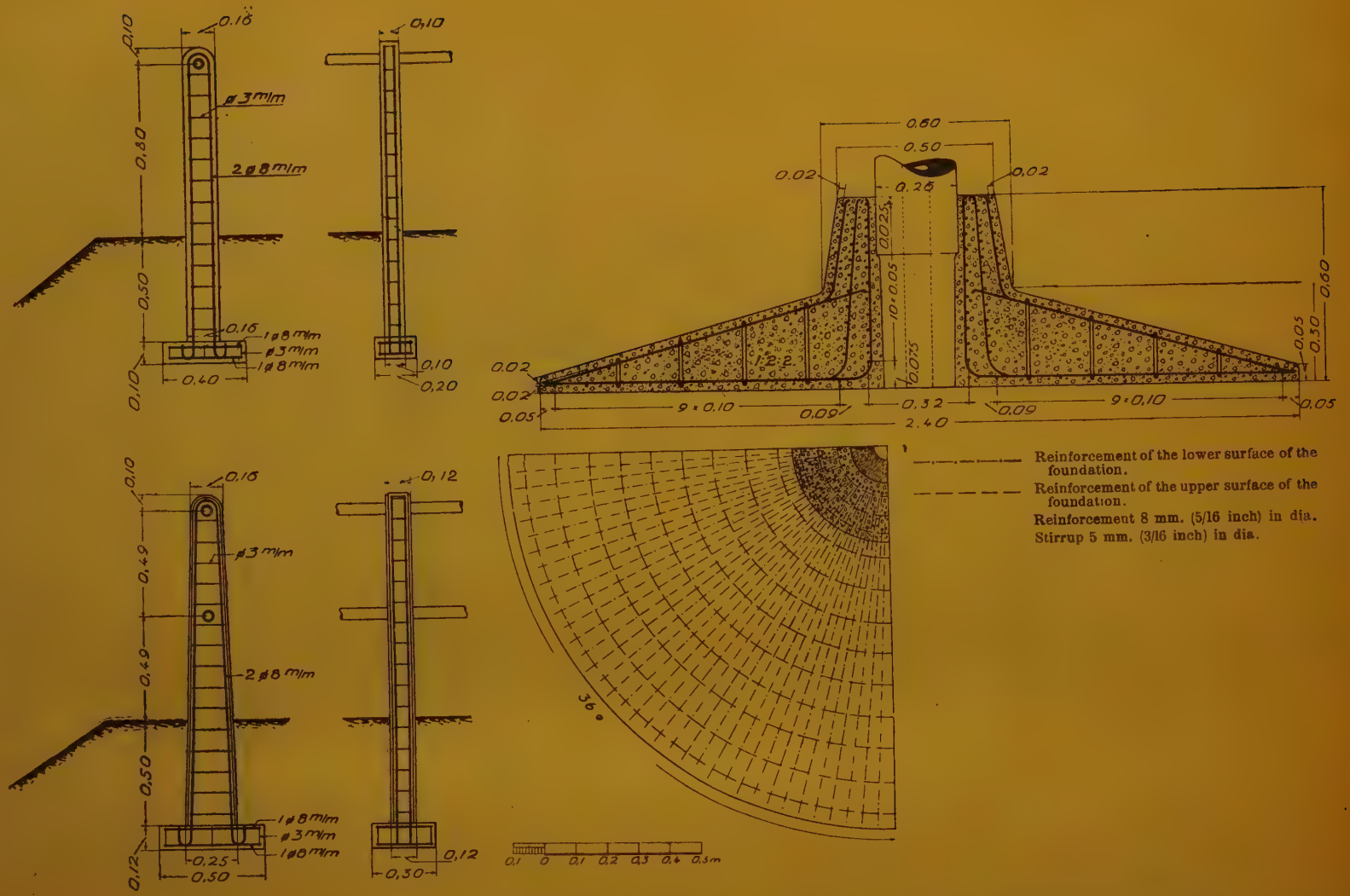


Fig. 69. — Transportable foundation for 35 cwt. crane (Danish State Railways).

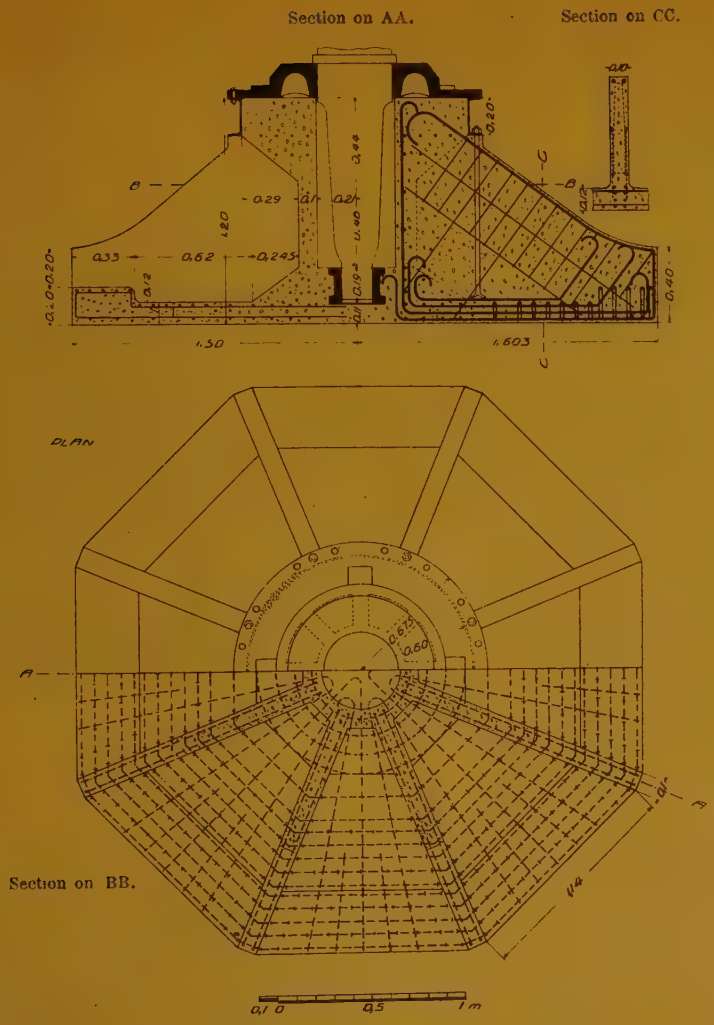


Fig. 70. — Transportable foundation for a 5.5 ton crane, weight = 5 665 kgr. (Danish State Railways).

CHAPITRE VIII.

Repair and strengthening of old structures.

An interesting piece of work of this class is the strengthening of the *Velanda railway bridge* on the Bergslagernas line in Sweden 9.3 miles south of Trollhättan.

The bridge in question was of iron and as shown in figures 71 and 72. Owing to the increased density of traffic the bridge gradually became too weak and consequently required to be strengthened.

A reinforced concrete arch was con-

structed under the large central span of the bridge with eight vertical supports also of reinforced concrete for carrying the old central girders. At the same time the lateral girders were supported by thin columns two on each side as shown in figure 73. All the main girders, the cross girders and the secondary girders were afterwards encased in concrete while at the same time a flooring of reinforced concrete was interposed between the main girders on which the ballast could be carried.

Figure 74 shows the reinforced bridge after completion. As will be seen, the abutments of the arch were formed by burying the lower portion of the central piers in concrete (fig. 73). The concrete arch itself has a span of 36 m. (118 feet) and a versed sine at the soffit of 16 m. (52 ft. 6 in.).

The execution of the work gave rise to various practical difficulties, because it was impossible to interrupt the traffic. In order to avoid dangerous vibration in the bridge during its reconstruction it had to be made temporarily independant of the load of the trains; with this object a scaffolding was constructed under the bridge of such strength that it was capable of carrying all the traffic during the work of reconstruction. The track was consequently temporarity raised by 0 m. 5 (1 ft. 7 3/4 in.) above its normal level.

The strengthening of the bridge was completed in 1913 and it has stood well. A short time after the completion of the work a loading test was carried out which did not show any appreciable deflection.

In Denmark also several widening and strengthening works have been carried out during the last few years. Among these one may quote the reconstruction and the lengthening of a road bridge carried out by the Danish State Railways over a double-track railway near Copenhagen.

The bridge in question, a « Monier » arch, is shown in its original form in figure 75, and as will be seen it crosses over a double-track railway. This line required to be widened to four tracks and for this reason it was necessary to reconstruct the road bridge. For local reasons it was not possible to construct a new arch similar to the first in lengthening the bridge, and it was decided, — in order to avoid lengthening the new bridge more than necessary, — to use only a portion of the old arch and to construct a new central pier between the old arch and the new arch symmetrical with the first.

Figures 77 and 78 show the manner in which the reconstruction was effected. After the old arch had been partly uncovered a new pier was constructed below it. After this the new arch was turned in such manner as to cut the reinforcement rods of the old arch near the lower edge of holes made for this purpose (fig. 76); these rods were then bent upwards in such manner as to permit of their being connected with the reinforcement rods of the new arch. Five weeks after the filling in of the new arch the remainder of the « Monier » arch was removed and the bridge was completed.

Figure 78 shows the completed bridge. The reconstruction, carried out in 1908 was effected without the slightest accident.

Among repair works, widenings and strengthenings, one may also mention the strengthening of a rather large road bridge in which some central piers were removed which had, proved to be too weak and which were replaced by stronger concrete piers. This reconstruction was

Fig. 71. — Railway bridge near Velanda before strengthening (Bergslagern Railway, Sweden).

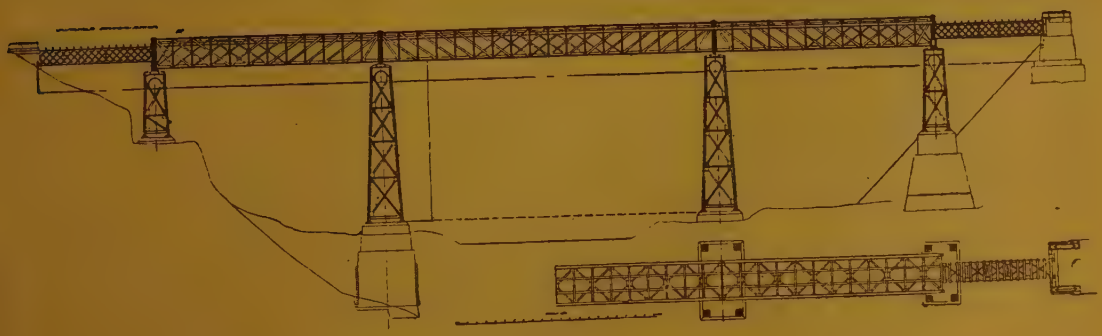


Fig. 72. — Railway bridge near Velanda before strengthening (Bergslagern Railway, Sweden).

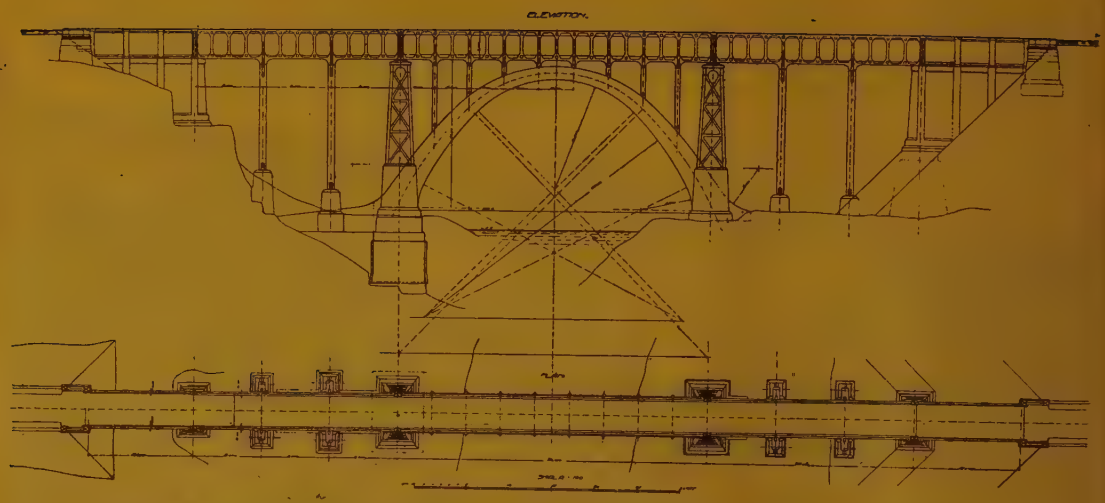


Fig. 73. — Railway bridge near Velanda after strengthening (Bergslagern Railway, Sweden).

Fig. 74. — Railway bridge near Velanda after strengthening (Bergslagern Railway, Sweden).

Fig. 75. — Road-bridge over two-track railway before reconstruction (Danish State Railways).

Fig. 76. — Road-bridge (fig. 75) during reconstruction (Danish State Railways).

Fig. 77. — Road bridge (fig. 75) during reconstruction (Danish State Railways).

Fig. 78. — Road bridge (fig. 75) after reconstruction (Danish State Railways).

carried out without interrupting the traffic over the bridge.

Finally we should add that in some cases old brick arches have been strengthened by a lining of reinforced concrete.

The lining was formed on the inside of the old arch after a portion of this had been removed to the thickness of a half-brick (about 15 cm. [6 inches]).

It should in any case be noted that repairs and strengthening of existing works are very often difficult to carry out and this is great disadvantage in reinforced concrete structures.

THIRD PART.

CHAPTER IX.

Proportions of concrete, reinforcing bars and permissible stresses.

In the selection of the proportions for mixing the concrete two things must be taken into consideration : first the strength of the concrete and secondly the impermeability desired. It is of the greatest importance, both for strength and impermeability that there should be sufficient mortar to fill the voids of the aggregate; and to obtain impermeability it is moreover absolutely necessary that the mortar itself should be dense. However, it is not always necessary that the mortar should be impermeable and the greater number of ordinary concrete structures are constructed, as is known, with permeable mortar; but, when it is a question of reinforced concrete structures, in which the iron must be protected from rust, or of reinforced concrete structures exposed to the infiltration of water or other liquids, one does not dare (unless the structure has a protective coating) to neglect the impermeability by the use of suitable mortar.

Structures of ordinary concrete, are generally executed in concrete of the proportions 1 : 3 : 5 (1 part of cement + 3 parts of sand + 5 parts of stone) or 1 : 4 : 7 (see Chapter IV), or finally in exceptional cases of 1 : 5 : 9; in these three proportions there is a small excess of mortar which is necessary when one desires to be certain that the spaces in the reinforcement shall be filled with mortar. The Danish State Railways also require that concrete mixed in these proportions should contain at least 404, 304 and 236 lb. of cement per cubic yard when it is mixed.

These proportions for concrete are accepted if the concrete is not exposed to running water or to infiltration. The proportion 1 : 3 : 5 is very generally used in the Northern countries for concrete structures which require to have considerable strength, but for which it is not desired to use reinforced concrete; this proportion is used, for example, in the concrete arches of large sewers, arches of bridges and works of this class; it has been used among other purposes to a great extent for the construction of the four-track tunnel for the Copenhagen underground railways. Moreover the proportion 1 : 3 : 5 is also often used in Sweden for making arched bridges in reinforced concrete.

Reinforced concrete structures are usually made in the proportions 1 : 2.5 :

3.5 or 1 : 2 : 3. The former proportion, particularly in Denmark, is very commonly used for interior work such as floors and similar structures, whereas in outside work — such as bridge construction — the proportion 1 : 2 : 3 is generally used (1). Concrete richer than 1 : 2 : 3 is rarely used; in some cases however — for piles and for work under water for example — more cement has been used up to 1 : 1.5 : 2.5. In Sweden, apart from the proportions named, the 1 : 3 : 4 mixture has also been frequently used during the last few years for reinforced concrete.

As will be seen, the proportions used for reinforced concrete are very rich in mortar, which is doubtless necessary when it is required to make sure that the iron will be properly covered by the mortar; on the other hand the concrete must not be too rich in mortar owing to the contraction of concrete in setting, because this contraction — (and this is a source of the danger of formation of cracks in the concrete) — increases with the quantity of mortar. In Denmark, a few years ago, it was not uncommon to use the proportions 1 : 3 : 4 (as is the case at present in Sweden) for reinforced concrete structures, but this proportion has now been completely abandoned and replaced by the proportions 1 : 2.5 : 3.5 or 1 : 2 : 3, both of which are poorer in mortar and at the same time stronger.

The specifications usual in Denmark for reinforced concrete structures (specifications which apply particularly to buildings) require that the quantity of cement should be not less than 472 lb. per cubic yard of mixed concrete; to ensure that the concrete shall contain a sufficient excess of mortar the specification also requires that the quantity of stone in reinforced concret must not exceed the quantity of sand (or gravel) by more than 60 %. In the most recent specifications for the execution of reinforced concrete structures, the Danish State Railways have laid down still more severe requirements on the subject of the quantity of cement to be mixed in the concrete; it is required that a cubic metre of mixed concrete, of the proportions 1 : 2 : 3 or 1 : 2.5 : 3.5 should contain at least 600 and 514 lb. of cement respectively per cubic yard.

Regarding the *permissible stresses* in the concrete and in the steel in reinforced concrete structures it may be noted that the *Danish State Railways* have fixed different limits for the permissible stresses according to whether it is a question of the construction of houses (buildings) or of bridges : and in the case of the latter the permissible stress also differs according to whether it is a question of foot-bridges, of road-bridges or of railway-bridges. In the different classes of bridges the permissible stress also varies for the different portions of the structure : the slabs, the secondary girders and the main girders.

We give below a table of the permissible stresses — for steel and for concrete respectively, — on which the Danish State Railways have based their calculations for the different cases.

The permissible stresses in steel shown in this table only apply to mild steel having an ultimate tensile strength of at least 52 620 lb. per square inch; if steel is used of higher ultimate tensile strength the permissible stress has in some cases been increased.

(1) For outside structures of reinforced concrete it is doubtless necessary that a mortar poorer than 1 : 2 should not be used if the iron is to be protected against rust.

The *Swedish railways* have not given such exact information regarding this question.

We are informed that for old road-bridges, the permissible crushing strength of concrete is taken at not more than one-sixth of the resistance to crushing of a cube after twenty-eight days and in the case of new bridges not more than one fifth of the resistance to crushing of the cube. The permissible stress in the steel is calculated at not more than 14 220 lb. per square inch.

In the case of road-bridges and tunnels the figures are about the same; but the stress on the steel is taken as not greater than 12 800 lb. per square inch. At the same time it is stated that the effective rolling load should have a percentage added to it to allow for impact.

Table of permissible stresses :

CLASSES OF REINFORCED CONCRETE STRUCTURE.	Permissible stresses	
	For concrete.	For steel.
	Lb. per square inch.	
A. — BUILDINGS :	569	17 070
B. — BRIDGES :		
1. — *Foot-bridges.*	569	15 650
2. — *Road and street bridges* :		
a) Non-anchoved slabs	427	12 800
b) Slabs, girders of secondary length and transverse girders (for flooring) and also main girders loaded directly.	498	14 220
c) Main girders loaded indirectly, and structures of frame form	569	14 220
d) Arches and vaults	569	15 650
3. — *Railway bridges* (having at least 25 cm. [10 inches] of ballast under the sleepers) :		
a) Non-anchored slabs	356	11 380
b) Slabs, girders of secondary length and transverse girders (for flooring) and also main girders loaded directly	427	12 800
c) Main girders loaded indirectly, and structures of frame form	498	14 220
d) Arches and vaults	569	14 220

Tensile tests of the concrete should give not less than 341 lb. per square inch.

The Norwegian State Railways adopt the German (Prussian) specifications of 1916.

In the three Scandinavian countries generally only round steel bar is used as reinforcement. In some cases the Danish

State Railways have, however, used corrugated bars, as for example in the construction of the large road-bridge in Copenhagen shown in figures 18 and 19. On account of local conditions that have been already mentionned it was very difficult to give this bridge the necessary depth; for this reason corrugated bars (Johnson ribbed bars) were used because by this means (on account of the square section of the bars) it was possible to use a greater quantity of steel at the bottom of the girders without involving the loss of a great portion of the effective depth of the girders; at the same time advantage was taken of the great tensile strength of these corrugated bars.

The Swedish railway have informed us that in some cases they used « Kahn » bars, but they do not recommend their use.

Finally, in order to make the report as complete as possible, we should state that expanded metal has sometimes been used for the reinforcement of slabs : it cannot, however, be said that the use of expanded metal for reinforcement has been much used.

CHAPTER X.

Supervision,

In our list of questions we asked one question relating to the methods for ensuring proper execution of concrete work, and all the replies agree in stating that this depends entirely on efficient supervision, on the site.

It is evident from the replies that it is necessary to exercise close inspection of the cement, the aggregate, and at the same time to watch most carefully the preparation and filling in of the concrete (see Chapters II and III); it is even stated that it is very important that the work should be entrusted to well-known firms employing engineers and foremen who are specialists in reinforced concrete construction.

We have also been informed by several Administrations that, in the case of large structures, the railways should themselves obtain the necessary materials in order to avoid false economies by the contractors in their own interest; this is certainly a good arrangement.

In the case of large works it is almost always specified that the mixing of the concrete should be done by machine. Density of ordinary concrete is ensured— apart from correct choice of the proportions of the mixture — by laying the concrete in layers not exceeding 20 to 25 cm. (8 to 10 inches) in thickness, and in carefully tamping it directly afterwards; in the case of large works of this class pneumatic tampers are sometimes used. In the case of reinforced concrete structures, density of the concrete is ensured — assuming the proportions to be correct — by adding a slightly greater quantity of water so that its consistence may become more nearly that of porridge, and that it can pass between the bars and the stirrups with ease and enclose them completely, when the concrete is worked with suitable tampers. The tamping of the concrete is of great importance, both in the case of concrete made wet and in that of concrete fairly dry, and if the bars (which should be carefully placed as shown on the drawings) are not too closely spaced it is possible to obtain a dense result by the careful working of the concrete.

In the three Scandinavian countries the testing of the strength of the concrete is effected by means of cubes which give the resistance to crushing after

twenty-eight days. But in the course of the last few years the Danish State Railways (as is also the case elsewhere in Denmark) require tests to be made of test-bars (beams); these tests have the great advantage of being able to be carried out on the site without the assistance of machines and in the presence of the workmen who should be present at the tests for educational reasons.

The test beams have a length of 2 m. (6 ft. 6 3/4 in.) and a transverse rectangular cross-section of 9 cm. deep and 6 cm. 5 wide (3 1/2×2 9/16 inches); they are reinforced with round bars 12 mm. in diameter (15/32 inch) embedded at a depth of 5 cm. (2 inches) measured from the centre of the steel bar to the upper surface of the test-beam.

The test-beams (prepared with concrete,

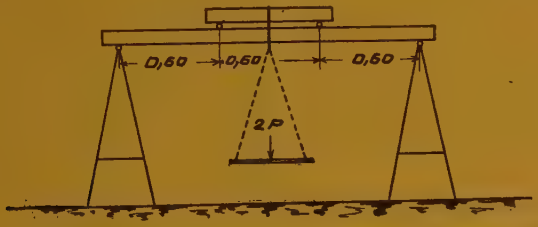


Fig. 79. — Appliance for loading test-beam (Denmark).

Fig. 80. — Test-beam under load (Danish State Railways).

mixed and tamped in the same manner as the concrete being used in the structure), are tested after a period of twenty-eight days to which number are added, the number of days on which the temperature of the works has been below 4° C. (39.2° F.). Figure 79 shows the arrangement of the loading gear; the test-beam is placed on two supports 1 m. 80 (6 feet) apart and is subjected to two

equal loads, W, gradually increasing and each acting at 60 cm. (2 feet) from the supports. The total load 2W acts directly on the middle of a secondary beam from which the pressures W are transferred to the test-beam as will be seen in the illustration. After fracture the load 2W is measured and the position of the steel bars in the test-beam checked, after which the resistance to compression of the concrete is taken from a table calculated for this purpose.

Figure 80 shows a test-beam under load.

The Danish State Railways require that the concrete shall have a resistance to crushing in the case of the cubes and of the beams respectively at least as follows :

MIXTURES.	Test cubes.	Test beams.
	Lb. per square inch.	
1 : 2 : 3. . . .	2 845	3 556
1 : 2 1/2 : 3 1/2 .	2 560	3 200
1 : 2 1/2 : 4 . .	2 347	2 845
1 : 3 : 5. . . .	2 133	2 560

Two test-beams are usually made for each 20 000 kroner (or fraction of 20 000 kroner) of value of the reinforced concrete structure.

One point to which the attention of the engineer-in-charge must be most carefully directed is to see that the shuttering is not removed too soon.

The particulars which have been supplied to us on this subject show that, throughout Scandinavia, a difference is made according to whether the shuttering carries a load or only forms the outside of the structure. In the latter case the shuttering is removed, at normal temperatures (above 4° C. [39°2 F.]) after four or five days (the Swedish railways however require one week at least); on the other hand, in the case of shuttering carrying the structure, the necessary period for retaining the scaffolding depends on the span, and the usual period is from three to four weeks. With regard to this question instructions are given, for the execution of reinforced concrete structures in Denmark, that the period (when the temperature for the time occupied in hardening has not fallen below 4° C.) may be expressed by $4+3\,b$ days, where b represents the span of the structure in metres; but it is nevertheless necessary that in each case examination should be made to ascertain whether the material has set sufficiently.

Many replies show that a saving of expense in shuttering could be effected, if this were fixed in such manner that it could be used several times. Arrangements made with this object are naturally advantageous if they do not lead to the removal of the shuttering too soon. The Swedish and Norwegian Railways also point out that if the boards are properly fastened together and used several times, for example as in the forming of long retaining walls, it is possible to reduce the expense of the shuttering to an appreciable extent, which is what might be expected. In the construction of the underground railway tunnel running through Copenhagen, the scaffolding of the shuttering of the arches was used several times with the saving of a considerable sum; this had, however, a natural result in increasing the length of time occupied in the work. Many other works, such as the making of concrete pipes, of posts for railings and fences, etc., also lend themselves very well to the repeated use of shuttering. In the designing of each form of structure in reinforced con-

crete this point should allways be taken into consideration (for example in the design of a building in reinforced concrete of several floors or of a long bridge or other work of such nature); it cannot, however, be stated that the replies relative to the question of reduction of expense of scaffolding or of shuttering have brought anything new to light.

There is nothing new to report regarding the methods of ensuring the correct placing of the steel reinforcement during the concreting; attempts are made as far as possible to connect the bars rigidly with others by means of stirrups in such manner that they cannot become displaced during the tamping of the concrete; the reinforcements of columns are, in most cases, rigidly inter-connected before being placed in the shuttering; in arched bridges the tension bars are often connected by stirrups in groups or sections before they are placed on the scaffolding, in such manner that they may occupy a definite position when they are put into place. By this means the assembling of the steel frame work on the scaffolding is accelerated because the work of erecting is reduced to that of placing the groups of bars in the shuttering and afterwards introducing the distributing bars and attaching them to each other.

Good execution of the structure depends, moreover above all, on the engineer superintending at the yard, on his intelligence and conscientiousness and it is particularly important, as we have already stated, that the engineer should be thoroughly familiar with the principles on which the calculations for the structure have been based — calculations which have, in many cases, been carried out by another party — because it is only possible by this means to prevent such errors as wrong stoppages in the filling, bad assembly, too short overlap of the bars, poor material, etc.

At the time that the works are being carried out in reinforced concrete it should always be specified *that the drawings and calculations should be examined and signed by the engineer who is responsible for the work done on the site* and it has also been considered advisable to adopt this plan in the most recent specifications for the execution of works in reinforced concrete in Denmark.

CHAPTER XI

Durability of reinforced concrete structures and the adaptability of concrete to resist external forces.

The question of the durability of reinforced concrete structures is one of the problems that has occupied the attention of technical men for several years and that has attracted the greatest interest everywhere.

In Scandinavia,as throughout the world where reinforced concrete structures are being made, examples are found of work which has failed and which has consequently collapsed, examples of structures of reinforced concrete in which, with time, cracks have formed — large or small dangerous or otherwise — and also examples of reinforced concrete structures in which the concrete (and possibly the reinforcement also) has deteriorated due to outside influences which had not been foreseen.

If we seek the reasons for this state of affairs they will be found partly in the engineers' offices in which the reinforced concrete structures have been designed and the calculations made, partly on the site where the structure was built, and finally in special circumstances that exist-

ed at the time when the structure was being made.

If deterioration arising directly from errors in the designs, bad construction, mistakes in the calculations or other errors of this class, are left out of account— as well as errors on the site due to want of special knowledge of reinforced concrete work — we think that the formation of cracks or fissures in the greater number of old reinforced concrete structures arises from the fact that account has not been taken of the stresses produced by the concrete; stresses which have arisen after the casting and particularly stresses due to the contraction of the concrete during setting and to those due to expansion by heat.

A tensile stress, as is known, may be a source of anxiety in a reinforced concrete structure if reinforcement capable of resisting the forces has not been incorporated in it; and the cracks of which we have spoken may be prevented by proper design, such as the provision of expansion joints not too far from each other, or, as has been said above, by the use of adequate steel reinforcement.

In the last large reinforced concrete structures built in Denmark, particularly in the construction of bridges and works of this class (but rarely in the case of buildings) — account has been taken in the calculations of changes of temperature from 10° to 20°C (50° to 68°F) according to whether the structure is protected from the direct rays of the sun or not, and according to whether it is a question of a massive or thin structure. Account is also taken in the calculations of the contraction of concrete by adding 15° C. (27° F.) to the variation in temperature. Finally, as we have already said, expansion joints are used wherever they are necessary.

The number of expansion joints that should be adopted depends on each structure and is determined specially for each piece of work. It appears, however, that the rule in the Scandinavian countries is to arrange expansion joints in long concrete walls, tunnels and other structures about every 20 to 25 m. (66 to 82 feet), just as it is necessary to divide large areas of concrete into small sections, which measure only 25 to 35 m. (82 to 115 feet), by expansion joints.

A certain number of reinforced concrete structures in which expansion joints have been used may be quoted; for example, the four-track tunnel, 1 500 m. (1 640 yards) in length constructed in Copenhagen by the Danish State Railways and divided into sections 18.7 m. (61 ft. 4 in.) in length by expansion joints; a bridge of about 120 m. (394 feet) in length and 40 m. (131 feet) in width (superficial area about 4 800 m² (51 700 square feet), constructed in front of the Copenhagen central station, so as to form a yard divided into five parts of from 800 to 1 200 m² (8 600 to 12 925 square feet) area; two roads 80 m. (262 feet) in length leading to this yard (and also carried on bridges constructed of reinforced concrete) which are divided into two parts, each about 40 m. (131 feet) in length, by expansion joints, etc.

In making application of expansion joints it should be thoroughly kept in mind that the joints must cut right through the whole of the structure, for, if not, as the result of the movement that takes place in the joints, it is difficult to avoid cracks in a continuous portion of the structure either above or below the expansion joints. The expansion joints are often a weak point in the structure, because they have not always been carefully designed, and the formation of

cracks may be noted, in cases where they have actually been a source of danger, arising from expansion joints that have been constructed on lines that were not rational, or as the result of sliding bearings (for girders) that had been incompletely finished.

With regard to the formation of cracks and fissures in the concrete we should note finally that these are often caused by incompleteness of the work and that, for this reason, effective supervision on the site may greatly diminish the danger of the formation of cracks. The contraction of concrete occurs, as is known, in the mortar; and if, on the site, care is taken to use large aggregate instead of fine, very little water is used in the preparation of the concrete, and suitable stoppages made in the filling, and lastly, — and this is by no means least important — if care is taken that the concrete does not dry too rapidly (for example by ensuring that the concrete is kept wet for about two weeks after moulding), it is possible in the majority of case to prevent cracks.

We do not wish to overlook the replies to the list of questions concerning a last point, that, relating to the solidity of reinforced concrete structures and of their being satisfactorily carried out. *This is the danger of putting up the construction of large reinforced concrete structures to public tender.* This causes without doubt danger as to the good execution and strength of the work, particularly if it is offered under conditions which leave the design of the scheme to the contractor himself. Owing to competition the contractors tendering are tempted to build improperly designed structures and to attempt false economies with regard to the dimensions and proportions of the concrete, the incorporation of the reinforcement, etc.; for our part we advise strongly the opposite procedure in placing the orders, that is to say that in which the administration of the railway not only prepares the whole of the design for the structure, but in which it also supplies all the materials, so that the carrying out of the work alone is left to the contractor under the permanent supervision of the railway officials.

In our list of question we asked whether experiments have been made relating to the destructive influence of *smoke from locomotives, of fires, of electric currents and of sea water* on concrete.

With regard to *the influence of smoke from locomotives* on concrete, experience appears to show that no trace of damage is found when the concrete is solid and thoroughly set. The Norwegian State Railways inform us that the reinforced concrete locomotive sheds constructed at Aal have stood for six years without the appearance of any injury to the concrete. The Swedish State Railways also have not found any bad effect from the smoke of the locomotives. The Danish State Railways made trials on this matter a few years ago, some pieces of concrete were suspended in a locomotive shed in such manner that they were much exposed to the smoke of the locomotives; these trials also showed that there was no deleterious effect on the concrete.

Locomotive smoke contains, however, sulphuric acid and all acids are dangerous to concrete; in confirmation of this it may be remembered that it was observed that, in the German railway tunnels, a coating of cement mortar recently applied was strongly attacked by the sulphuric acid in the smoke, and that in other German tunnels exposed to filtration of water considerable repairs had to be undertaken due to the effect of sulphuric acid. Doubtless

the chemical composition of the coal is of importance on this point, because all coals do not probably act in the same manner, but we think that in every case one ought, as far as possible, to avoid exposing fresh and newly laid concrete to smoke from locomotives.

A question relating to the durability of concrete is that of knowing to what extent the formation of cracks which are so frequently found in reinforced concrete structures, entail danger of formation of rust on the reinforcement and hence the danger of the destruction of the structure. The Scandinavian railways have not made special experiments in this field, but we are aware, — from the results of researches made in reinforced concrete bridges in Germany and Austria, — that, in many of these, traces of rust have been found on the reinforcement, and that this arises from fissures occuring at places where the concrete was particularly porous. In Germany experiments were undertaken to elucidate this question; these experiments were carried out in the following way : cracked girders were exposed so that the lower face could be subjected to the action of water vapour containing a large amount of acids. The result of these experiments appears to show that the effect is unimportant when the cracks are so full that the circulation of the air in them is very small, but, on the other hand cracks forming large openings may be dangerous.

The condition requisite for the preservation of the reinforcement in the concrete is that it shall be covered everywhere with a full coating of (rich) mortar,while the thickness of the coating is, as might be expected, of less importance. Generally the coating of concrete is, however, much thicker in the case of external structures than in the case of internal structures, and, in Denmark, the layer of concrete is usually made from 1 to 2 cm. (3/8 to 3/4 inch) in thickness for internal structures, whereas for external structures the thickness is increased up to 2 to 3 cm. (3/4 to 1 3/16 inches) and sometimes up to 3.5 cm. (1 3/8 inches).

The unexpected formation of cracks in concrete quoted above, is one of the difficulties that is found wherever reinforced concrete structures are built and doubts are expressed everywhere as to the danger these may cause to the structures. The Swedish State Railways write that they have begun to make active investigation on rational lines as to the formation of cracks in old reinforced structures. The Danish State Railways are also engaged in making similar researches; in Germany, as we have stated, this question has been under investigation for many years. It is possible that these researches may mean that, in the reinforced concrete structures of the future, lower tensile stressess should be adopted as a basis of calculation, and that heavier reinforcement should be used and particularly that the reinforcement should be used in places where, up to the present, it has not been thought on theoretical grounds to be necessary; reinforcement is now frequently incorporated, as is known, to the extent of two or more continuous reinforcing bars in the side of a girder exposed to compression just as reinforcing bars are incorporated in each bracket. From the economic point of view the increased expenditure arising from a heavier reinforcement will not be serious, and, if the formation of cracks can be prevented by this means, it will constitute a really great advance.

The Scandinavian railways have not made any special experiments with re-

gard to *the influence of fire and of electric currents on concrete.* The protection offered by reinforced concrete structures against the destructive action of fire is, however, a question so well understood that it is not necessary to deal with it at greater length.

With regard to the question of *the resistance of concrete to sea water* we have very little data. We have been informed, however, that the concrete has stood well, which is doubtless the general experience, provided that the mixture has been rich and the steel seinforceing bars (in the case of reinforced concrete structures) have been placed 2 to 3 cm. (3/4 to 1 3/16 inches) from the surface.

If the impermeability of the concrete is such that the water does not come into contact with more than the surface, the chemical action is extremely small. If, on the other hand, the concrete is porous, filtration of water proceeds and dissolves the carbonate of lime or causes this to undergo change, so that, with lapse of time, the concrete is destroyed.

Here, however, we are faced with the fact which is not a special characteristic of sea water, but is common to all waters of infiltration, that all of these have a destructive influence. All tanks, tunnels, roofs, bridges and works of this class should, for this reason, be formed of watertight concrete or covered with a watertight covering.

In structures where fairly large infiltration of water has taken place stalactitic formations may be seen which afford evidence of the commencement of the destruction of the concrete. Figure 81, for example, shows some concrete pipes which have been completely destroyed by the infiltration of water.

Running water, like water which filters in, is dangerous when it flows over porous concrete. In most of the cases in which destruction of concrete has taken place the reason has doubtless been that the concrete was porous.

Fig. 81. — Concrete pipes destroyed by infiltration.

The question of the impermeability of the concrete (to water, to the smoke of locomotives and to other influences) *is for this reason, in our opinion, of great importance and doubtless touches one of the vital points in the future development of the use of reinforced concrete.*

The protection of concrete against infiltration of water is generally effected in Scandinavia by coatings of bitumen, callendrite, asphalt, inertol, icopal, fluat, ceresit, etc., according to the class of structure.

The costs of maintenance of reinforced concrete structures obtained up to the present in Scandinavia have — as far as can be ascertained from the particulars we have received — been very low, this is probably due to the small amount of work which has been done to remedy the cracks which have appeared.

We are inclined to think that the experiments that have been made point out that the expenses of maintenance of concrete and reinforced concrete structures are much less than those corresponding to iron or steel structures, but that the expenses of maintenance would be scarcely any lower than those of similar structures in brickwork, — and perhaps even higher than in such structures.

CHAPTER XII.

The appearance of reinforced concrete structures.

In the design of any class of work whatever, it is not sufficient to take the purely technical side of the question alone into consideration (that is to say the strength of the structure), but it is also necessary to watch from the aesthetic and artistic points of view, that the structure shall present an artistic form and in this respect the structures built in reinforced concrete during the last few years have often left much to be desired.

In the higher engineering technical schools architecture generally takes a rather low place, and the engineer who is entrusted with the designs is often tempted by his calculations to look no further than the static and economic aspects of the question while at the same time he forgets that architecture porhaps requires much larger dimensions, for some parts of the structure, for example massive columns, or piers, or perhaps a totally different form of construction.

There is no doubt that in this respect (in all cases when it is a question of large works or reinforced concrete) collaboration between the engineer and the architect at an early stage of the work, — for example in working out the sketches for the first schemes — is to be recommended and we think would lead to better results

The question of the appearance of reinforced concrete structures comprises two points, the question of the form of the structure (the outline) and the question of improving the appearance of the external surface of the concrete.

The first is doubtless the most important so far as the appearance of the work is concerned, and a structure should always be built in such manner as to be in harmony with the character and nature of reinforced concrete.

A reinforced concrete structure should convey to the onlooker the story of the forces acting upon its various parts and the true form of the structure should not be dissimulated by coatings, imitation joints, etc.

This new material requires to be given a new form to correspond to its character, — large uniform surfaces without too many cornices or projecting ornaments, and without lines which might indicate joints and give the impression of hewn stone, of granite or of sandstone and which ordinarily only give a sham appearance to the structure, particularly when cracks, which are almost always unavoidable in concrete structures, are seen running through several outlined blocks.

A concrete structure, like any other, should be constructed in such manner that the material of which it is built is recognizable. But at the same time the treatment of the external surface of the concrete plays an essential part in the appearance of the structure.

Many reinforced concrete structures are not treated in any way on the surface or at the most are covered with a thin coating of cement, the grey and dull colour of which gives them a dull and disagreeable appearance, – particularly when the surface, as nearly always happens, is

covered with a network of small cracks arising from the contraction of the outer layer of cement. Frequently one even sees the imprint of the rough boarding of the shuttering showing so plainly in the concrete that one may almost doubt whether one is looking at a concrete wall or a wall of planks.

A really durable and beautiful method, — and at the same time cheap, — for improving the surface of the concrete is therefore of the greatest importance to the question of reinforced concrete.

The replies to the list of questions which we have received show that attempts have been made to improve the surface of reinforced concrete structures by different methods, for example by forming the concrete in moulds that have been planed or plastered so as to obtain a smoother surface; by applying special concrete at the external surface of the walls which are afterwards « rough-hewn », or finally by covering the surface with a special coating.

The first method in our opinion does not generally give good results; it is true that the imprint of the planks on the concrete is avoided by using a plastered shuttering, but this smooth surface of concrete is usually covered with stains and hardly ever looks well.

The application of special concrete for the outside surface, so that it may be subsequently « rough-hewn », is very often used and often gives a good result; that is to say it makes a good imitation of granite, — but the process is very expensive.

Generally the best results are obtained by the use of a coating which is applied to the surface, particularly when this coating is coloured, — not with artificial colours which fade — but with stones of different colours reduced to powder. A particularly fine result has thus been obtained by the coating on the retaining walls of the Copenhagen underground railway of which we have spoken in Chapter VII.

The ease with which concrete can be adapted to *architecture* is a great advantage for reinforced concrete, as a whole as well as for details, and the parts with artistic and decorative outlines (columns, balustrades, ornaments, etc.) which are made of concrete are many.

The essential point with regard to the general impression produced by a reinforced concrete structure is however — we repeat — harmony of construction, and is is often merely necessary that the lines of the structure should be good in order that the structure itself may appear good, — even though the original sombre and grey colour of the concrete is preserved.

CONCLUSIONS.

Taking as a basis the experiments that have been made in Denmark, Sweden and Norway on the subject of the application of ordinary concrete and of reinforced concrete on the railways of these countries, we propose the following conclusions :

1. — The use of ordinary concrete and of reinforced concrete on the Scandinavian railways, has, during the last few years, found a more extended field of application, and has firmly established itself in almost all of the classes of railway structures;

2. — Reinforced concrete replaces wood and steel with advantage in all structures which are not exposed to great impact or to vibration. Railway bridges proper are,

therefore, only constructed as arched bridges in which the effect of shock is in part transmitted to the embankment; or they are constructed as straight girder bridges with relatively short spans on which the ballast covering the bridge is of great thickness;

3. — The design and calculations of a reinforced concrete structure should be made according to the usual rules, the mode of construction and the numerous sources of error and misunderstanding which arise on the site being *always kept in view.*

The details of the structure should be carefully studied and the drawings executed in such manner as to be as easily read as possible; all the particulars necessary to obtain solidity of the structure should be clearly shown on the drawings.

Works in reinforced concrete, more than any others, require the permanent supervision of competent technical men on the site, men who have the necessary practical experience and who understand the principles on which the calculations for the structure have been based;

4. — Structures of ordinary concrete and of reinforced concrete should never be exposed to the infiltration of water, and if this is to be feared, the structure should be formed in dense, impermeable concrete or be suitably protected.

If dense concrete is used, as is always recommended for external structures, the experiments made up to the present have proved that (when the concrete is thoroughly set) there is no reason to fear damage arising from the smoke of locomotives, sea water, etc.;

5. — Among the advantages of reinforced concrete may be quoted the economy which it shows over steel, and at the same time it may be stated that reinforced concrete structures only require the minimum of expense in maintenance, when they have been designed on proper lines and when they are suitably protected against cracking due either to the contraction of the concrete during setting or to expansion by heat or to infiltration of water, etc.

The power which concrete possesses of being adaptable to various purpose should also be mentioned as it allows the erection of structures in reinforced concrete which from an aesthetic and artistic point of view give a pleasing result when account is taken of the nature of concrete;

6. — The good qualities of reinforced concrete, which greatly surpass its disadvantages will certainly obtain for it an ever increasing field of application on the Scandinavian railways and there is no reason for anxiety on the subject of reinforced concrete structures, — apart from the danger due to the effects of impact, — when these have been properly designed and constructed under the strict supervision of the railway administrations.

[621 .33]

REPORT No. 6

(all countries, except Holland, Great Britain, Belgium, Denmark, Norway, Sweden, Italy, Switzerland and America)

ON THE QUESTION OF ELECTRIC TRACTION (SUBJECT VIII FOR DISCUSSION AT THE NINTH CONGRESS OF THE INTERNATIONAL RAILWAY ASSOCIATION), (1)

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Fig. 1 p. 118.

I. — FRANCE.

General organisation. — In the middle of 1920 the French Government made regulations regarding the application of electric traction to railways of « general interest ». Three companies, the Paris-Lyons-Mediterranean, the Midi, and the Paris-Orleans, have proposed to electrify, within approximately twenty years, a total length of line of 5 000 miles. These companies have for a long time used electric traction on isolated sections of line, including an important network of lines in undulating country, or arteries having considerable traffic in mountainous regions, these regions being rich in water power.

After a long inquiry, carried out in collaboration by representatives of the State and of the railway companies, the Minister of Public Works has decided that the electrification of railways of general interest in France shall be subject to the following general regulations :

1° The primary distribution shall be by three-phase current, 50 periods, according to the conditions laid down for the great distributing companies, so that all the regional groups may have interchangeable electrical energy and may help each other mutually;

2° The traction current shall be continuous : its pressure is fixed normally at 1 500 volts (exceptionally at 3 000);

3° Every locomotive at 1 500 volts will be fitted with two current collectors, one being a third-rail current collector, and the other for the overhead line; and must be able to run and collect current on any line electrified at the same voltage.

The relation and discussion of the facts and studies which led up to this important decision will constitute the principal part of our report.

(1) This question runs as follows : « Electric traction on lines with much traffic : production and transmission of energy; type of current; locomotives, motor cars. Technical and financial results obtained. Comparison with the results of steam traction ».

Period prior to 1910. — Let us summarise rapidly the history of electrification in France before 1910, as reported to the Berne Congress.

In 1898, the Ouest Company and the Orleans Company constructed two new termini in the centre of Paris, the semi-underground station of the Invalides and the entirely underground station of the Quai d'Orsay. The latter, the future terminus of a large system, could only take smokeless locomotives. A commission of enquiry, sent by the Orleans Company to the United States in the Spring of 1898, brought back the desired solution, — traction by electric locomotives, — the value of which was guaranteed by the widespread use and good working of the installations in service in that country.

Inaugurated in 1888 at Richmond, the electric tramways, with their 12 400 miles of line, were running in all the great towns and suburbs of the United States. At Chicago 31 miles of metropolitan line were worked by motor-coach trains of more than 100 tons, and trials had been made with the first Sprague multiple unit train, that is to say, the prototype of the reversible and easily separable train, which was to transform the working of city lines and of the large termini. Finally, since 1895, the Baltimore & Ohio Railroad, desiring to suppress smoke in a new underground route at Baltimore, ran goods trains weighing 1 700 tons on gradients of 8 per mil., drawn by electric locomotives having two motor-bogies weighing 87 tons and developing from 1 500 to 2 000 H. P. The Chicago motor-coaches and the Baltimore locomotives worked with perfect regularity; they had simply adopted, on a larger scale, the arrangements peculiar to electric tramways; and, like them, utilised 500 volt continuous current. Already the traction current was obtained as a general rule by transformation of three-phase current distributed at high tension.

The Orleans Company entrusted the construction of its substation apparatus and electric locomotives to the General Electric Company, which had been responsible for those at Baltimore. The Quai d'Orsay station was inaugurated in June 1900, and henceforth was worked exclusively by 50 ton electric locomotives of 1 000 H. P., fed by 600 volt continuous current. The very satisfactory working of this first large underground electric station induced the directors of the Pennsylvania Railroad, in the following year, to abandon the project of the aerial crossing of the Hudson River in favour of a tunnel with a large underground station in the heart of New York, which was carried out between 1902 and 1909 (1).

In 1905, on the occasion of the quadruplication of its tracks, the Orléans Company extended as far as Juvisy 14.3 miles from the Quai d'Orsay, the electric traction of suburban trains, either by locomotives, or by multiple unit coaches.

Since 1901 the Ouest Company has run suburban electric trains from the Invalides to Versailles (11.2 miles) by locomotives and motor-coaches, which in

(1) In the « Historical Outline » which he gave at the annual dinner of the Diretors of the Pennsylvania Railroad in 1909, Mr. S. Rea, the Vice-President; recalled the event in the following terms : « Matters were, therefore. at a standstill. when in the Summer of 1901, Mr. Cassatt being in Europe, the opening of the extension of the Orléans Railway in Paris suggested to me that perhaps with the advance in electric traction, thus obviating the use of steam locomotives. we might be able to carry out a satisfactory tunnel scheme ourselves, nnd I cabled and wrote to Mr. Cassatt asking him to look over the Orléans work. This he did, and immediately replied that he was much impressed with it, and he believed it might offer the solution of our problem ».

construction and power resemble those of the Orleans Company, and which, like them, are fed by 600 volt continuous current, distributed by third-rail. In 1906 the Company decided to institute electric traction by motor-coach trains on its principal Paris suburban lines, with the object of increasing the capacity of the terminal stations of St. Lazare and Montparnasse, and to add an underground route. After the re-purchase of the Ouest line, in 1908, the State resumed and extended the programme of suburban electrification, the essential features of which it retained : Multiple unit, and 600 volt continuous current distributed by third-rail.

In 1901 the Paris-Lyons-Mediterranean Company opened up the Fayet-Chamonix line, since extended to Vallorcine (43.5 miles), of 3 ft. 3 3/8 in. gauge, and 90 per mil. gradients, on which traction is by means of motor-coaches, with 500 volt continuous current and third-rail. In 1905 the same Company began to experiment with transforming apparatus designed by its engineers Messrs. Auvert and Ferrand, and intended for the transformation, on an electric locomotive, of the single-phase current collected on the contact wire into continuous current supplying the driving motors.

From 1902 to 1908 the Midi Company entered into various agreements with the State, prescribing the construction at joint expense of new lines for electric traction, and the electrification of several existing lines. Further, the State conceded to the Company (at the same time contributing towards the cost) the harnessing of several waterfalls in the Pyrenees, the power obtained from which would feed these various lines. In the first place the Company applied continuous current (850 volts, third-rail and motor-coaches) to the line from Montagne de Villefranche to Bourg Madame (34.8 miles), metre gauge and 60 per mil gradients inaugurated in 1910. The general principle of the Company was, however, to electrify its normal gauge lines with single-phase current, 12 000 volts, 17 periods, by locomotives and motor-coaches. With a view to determining a type of locomotive and a type of overhead conductor, the Company equipped 24 kilometres between Ille and Villefranche, and invited competition for the provision of a locomotive of 80 tons and 1 500 H. P.

In 1904 the State electrified, by 2 400 volt continuous current, with double overhead contact lines the metre gauge line which it possesses in the Département de l'Isère, from St. Georges de Commiers to La Mure (19.3 miles long, 14.3 of which have gradients of 27.5 per mil. The line carries annually, on the down gradient some 300 000 tons of anthracite. The locomotives of 50 tons, 500 H. P., and two motor bogies, draw 300 tons down and 110 tons up the grade. Down hill the locomotive brakes its own weight by rheostat braking and the wagons are checked by a continuous vacuum brake. The locomotives, designed and constructed by Mr. Thury, work very satisfactorily and only require moderate attention; but, in order to avoid the complications of the double conductor, it has been decided to provide a single wire at 2 400 volts on the extension of the line to Cap, now in course of construction.

The economoy of working attributable to electrification was estimated at 30 per cent at the period of the change over.

Period subsequent to 1910. — The second period is divided into three parts by the war.

From 1910 up to the outbreak of the war, the companies engaged in electrifi-

cation continued the work which they had undertaken, adhering to their programme.

The Midi Company constructed new works and electrified several branch lines in the Pyrenees, equipping them with Westinghouse single-phase motor-coaches. Following on a competition in which trials were carried out with locomotives supplied by six firms, the Company placed an order for 24 machines, distributed among three firms. These trials were, however, delayed by the disturbance occasioned to the telegraph and telephone lines, which necessitated laborious study and research on the part of the Company.

In 1911 the Paris-Lyons-Mediterranean Company carried out trials on the Cannes-Grasse line (20 per mil gradients) with a single-phase 136 ton locomotive, fed by single-phase current, 12 000 volts, 25 periods, and fitted with the transforming apparatus of Messrs. Auvert and Ferrand.

The State enlarged its existing steam power stations and began new ones. It put into service on the Invalides-Versailles line 44 motor-coaches with 2 bogies, 18 coaches being 8-wheeled, of 59 tons and 470 H. P., the remaining 26 being 12-wheeled, of 74 tons and 740 H. P. Large orders were placed for rolling stock which unfortunately owing to the war had to be cancelled.

The Paris-Orleans Company in 1913 ordered for its suburban trains 5 locomotives of 86 tons and 1 800 H. P. of the 2-8-2 type carrying in the locomotive two large motors which drive the coupled axles by means of rods arranged on the Buchli or two-rod system.

The drive embodies a flexible or spring coupling as suggested by Mr. Parodi, the chief electrical engineer of the Paris-Orleans service.

Held over by the war, these locomotives are now in course of delivery.

The war suspended all work on the lines or on rolling stock, and accelerated the construction of water and steam power stations, the power provided by which was utilised by various industries. But if work ceased, ideas continued and were directed towards a vast programme of electrification. The crises in production and transport and the cost of coal gave food for reflection; close consideration was given to the resources afforded by water power; in particular it was ascertained that in the Massif Central there exists available energy to produce five or six hundred thousand H. P., the regular production of which it is possible to control by the construction of large seasonal reservoirs.

At the same time, in the organisation of intensive strategic transport, the three-phase system of the Italian State Railways gave a striking demonstration of its power of developing the capacity of the most difficult sections. Then we learned of the success of new systems introduced in the United States.

The Orleans Company which serves the greater part of the Massif Central, took part in the study of its water power development, drew up a programme for the electrification of 1 240 miles of line, and at the end of 1917 applied for the concession of a group of waterfalls on the Haute-Dordogne and its tributaries. At the invitation of the Administration it increased to 1 865 miles the length of line to be ellectrified, which extends from south to north, from the Midi railways to Moulins and Châteauroux. Some months later, the section Châteauroux-Paris was added, thus completing the great north to south artery from Paris to Toulouse (467 miles).

The application for the concession of the Dordogne falls was considered and a rapid investigation was made; but consent was not given by law until July 1920

owing to legislative difficulties which impeded hydraulic concessions.

For its part the « Compagnie du Midi » extended its programme to the greater part of its system — 1 680 miles out of 2 485; and applied for further concessions of waterfalls, particularly on the Cave d'Ossau, on the Ariège and on the Têt.

Immediately after the Armistice, on the 14 November 1918, the Minister of Public Works, who had received the proposals of the Midi and Orleans Companies, instituted a committee composed of representatives of the State, of the Railways and of Industry, and entrusted it with the technical, economic and financial study of the operations to be effected or undertaken for the electrification of railways of general interest.

The Committee appointed two Commissions, one technical, the other administrative, which both include the same acting members. The technical Commission organised missions of enquiry which visited the principal electrified lines of Switzerland and Italy in January and February 1919, of the United States in May, June and July, and of England in November.

On the 15 May 1920 the Committee presented to the « Conseil supérieur des travaux publics », who approved them, the conclusions a summary of which is given at the commencement of the present report.

The members of the various missions arrived at a unanimous decision, and the Committee unanimously approved their proposals.

The work of the Committee and of the Commissions formed the subject of an official publication of the Ministry of Public Works. Important reports were published on the work of the missions by engineers who took part in them (1).

The mission to the United States exercised a preponderating influence in the final decision. We must refer to it in some detail.

The mission consisted of eleven members : a professor of electro-technics and ten railway engineers. Of these ten, five are specialist electricians, with long practical experience of electric traction on their railways, and well-informed as to foreign practice. The other five, who are not specialists, are principals, or chief-assistants, of important branches of the service, almost all of them having had to direct electric working, being able to compare electric traction with steam traction, and knowing the practical problems involved by a change from one system to the other.

The mission was accompanied by two telegraph engineers, sent by their administration to study particularly the serious question of the influence of traction currents on telegraph and telephone circuits.

On their departure the majority of the members inclined towards the single-phase system, either in theory, or in the light of previous practical experience. On

(1) « Provisional report of Prof. Mauduit on the mission to the United States ». (*Journal officiel* of 13 August 1919). (See also *Bulletin of the International Railway Association* October-December 1919 p. 273. — « Note on electric traction in Italy », by M. Parodi, chief Electrical Engineer, to the Orléans Railway Company, *Revue Générale des Chemins de fer*, November 1919. — « Electric Traction in the United States », by Messes. Japiot, Chief Engineer for Rolling Stock and Traction of the Paris - Lyons - Mediterranean Railways, and Ferraud, Chief Engineer of the « Office Central d'Etudes du Matériel de Chemins de fer » (*Annales de Mines*, October 1920 to March 1921), edited by M. Dunod.

their return there was unanimous and unreserved adhesion to traction by high tension continuous current with regenerative control, and the telegraph engineers had recognised that the system had no harmful effect on telegraphic circuits. This unanimous conclusion, in our opinion, weighs more heavily in favour of the system chosen than the most learned technical discussions. The latter have already received great prominence, and might be continued indefinitely without convincing anyone interested in the question. We remember the dispute, which was as animated as it was futile, between the advocates of the flat bottomed rail and the advocates of the double headed rail : the dispute died away and nobody dreams of reviving it.

Let this example be a lesson to us, inducing us to leave to each one the liberty of choice, when he bases his choice on theoretical data or incontestable practical experience, with the conviction or the illusion that his judgment is correct.

If it is desirable that within any one country electrification should be regulated by uniform rules, international regulation is of less importance. In times of peace the steam locomotive, which is impeded by no technical obstacle, does not cross the frontiers : why then trouble to give the electric locomotive a theoretic capacity which it will never utilise? The complication caused by the meeting of two different methods of traction in one common station is not very troublesome, and the number of stations so affected is very restricted.

We will examine briefly the considerations which have influenced the French mission and determined its choice.

1. *Telegraphic circuits.* — The question of the influence of traction currents on telegraphic circuits is of considerable importance in France, greater in fact than in most other countries.

Our Postal and Telegraphic Service has the free use of the railways for the establishment and maintenance of its lines : it exercises this privilege to the utmost limit, and our main permanent ways are crowded with innumerable wires.

If we required it, their displacement would be carried out by the Postal Service at our charge, without our having any control over the arrangements or expense.

The representatives of the Service found that, on the Rocky Mountains line, the system of traction by high tension continuous current does not adversely affect the neighbouring telegraphic circuits, although no special provision has been made for protecting them.

In the United States, however, as well as in Switzerland, Italy and France, the engineers of the mission saw what complicated, burdensome and often inadequate precautions were necessitated by the use of alternating traction current. The system has the advantage of a higher voltage, which would reduce the number of sub-stations : in the United States, to protect the telegraphic circuits it has been necessary to multiply the number of sub-stations to such an extent as to reduce the average distance between them to 6.2 miles on the Norfolk and Western line and on the suburban lines of the Pennsylvania Railroad, near Philadelphia, which are electrified by single-phase current of 11 000 volts, 25 periods. On the latter lines it has finally been necessary to instal two synchronous motors, in order to mitigate voltage variations.

2. *Multitraction* (1). — The two prin-

(1) *Multitraction.* — This expression is used throughout this paper when referring to the working of trains by means of two or more locomotives, *i. e.*, one in front and the other at the rear, or with an additional locomotive in the middle of the train.

cipal cases of electrification of heavily graded lines in the United States — that of the Norfolk & Western (29 miles) and that crossing the Rocky Mountains (441 miles) have had as their main object the increase *of their capacity.*

The first, a double-track mineral line, which has a tunnel of 1 040 yards with single-track, has to cope with enormous traffic of more than 18 million tons; it is constructed with long gradients up to as much as 23.6 per mil. in one direction and 20.6 in the other; the radius of curves is as small as 7 1/2 chains.

The line crossing the Rocky Mountains is single-track, with loops at very wide intervals; its profile shows long gradients of which the maximum is 20 per mil. The weight hauled is 6.4 million tons per annum.

The two lines are worked by very heavy trains, the weight of which is determined by the strength of the American couplings On both lines constant use was made of auxiliary steam locomotives in ascending gradients, using the Westinghouse continuous brake, combined with retaining valve, in descending. In the case of both Companies the increased capacity made it unnecessary to double the track or to modify the gradients, which would have been much more difficult than electrification.

The electrical regenerative control now adopted on these two lines has diminished the wear of the stock and increased the safety of trains in the descent of long gradients; this latter advantage is small in the case of trains fitted with the continuous brake. The increase of capacity, the principal advantage secured, arises from other causes.

On difficult grades the commercial speed of a train with a single locomotive is limited by the continuous power of the locomotive and its load, and by the strength of the couplings. The first difficulty is surmounted by maintaining the output of the locomotive; the second is overcome by *multitraction.*

Every system of electric traction gives the former advantage : even if it is easy to obtain the same adhesion weight and the same instantaneous tractive effort on an electric locomotive and a steam locomotive, the first only has, up to the present, been able to maintain indefinitely its normal effort, and that because it is not encumbered with apparatus for the production of energy. It is free from falling off in power which on long gradients, is caused by prolonged heavy steaming. On the Norfolk and Western, for example, electric traction has made it possible to increase the speed of trains on heavy gradients from 7 to 14 miles, and has eliminated the breakdowns which were frequent.

The straight single-phase current would have given the same results if a train with a single locomotive had been employed. It is the necessity for multitraction which has led to its rejection and made it necessary to accept the great complication of transforming the current on the locomotive itself.

Experience in Italy, on the Norfolk & Western, and on the Chicago-Milwaukee has shown with what facility and surety multitraction adapts itself to the three-phase, split-phase and continuous current systems, whereas hitherto there existed no example of multitraction of heavy trains on heavy grades by the straight single-phase current.

The reason for this is well-known : during starting, the single-phase motor, at any rate at the frequency employed in the United States, is not satisfactory unless there is perfect balance of the load between the motors placed at intervals along the length of the train. We believe

that this defect can be easily corrected, for example, by employing a method of connection between motors similar to that to which we shall refer later : this was not so at the time the mission carried out its investigations, and this was a serious objection for the three French Companies, in whose case electrification will principally deal with mountain lines.

The particular configuration of its railway system has, further, led one of them, the Orleans Company to seek to improve multitraction by a permanent and reliable system of connection between separate motors, which should give the driver at the head of the train complete control over the whole train.

The so-called saw tooth profile, fairly rare on the two other French railways, is on the other hand very frequent on the lines of the Orleans Company which are to be electrified, which cross or skirt the Massif Central, encountering successively a large number of secondary valleys.

In climbing a gradient, the auxiliary engine is placed in the middle or at the end of the train, according as the latter is or is not fitted with automatic brakes. If the gradient is exceptional, the auxiliary engine, on arriving at the summit, leaves the train or passes to the front. But passage from front to rear at each rise or descent would be impracticable on the « saw-tooth » lines : multitraction is only admissible on these lines if the auxiliary engine can retain its position in the train, either at the rear or in the middle.

This is the method obtaining on the Rocky Mountains line.

On this line, however, the continuous brake establishes a permanent connection between the engines, incomplete it is true, but which gives the driver at the head of the train independently the power of stopping the train when he meets a stop signal which the driver of the auxiliary engine may be unable to see.

Another, and for us more interesting, case of multitraction is that of the Italian line from Savona to Ceva, without the continuous brake. The line, which is 28 miles long, crosses three high points, rising and descending by gradients of 25 and 27 per mil. Along the whole length goods trains of 460 tons are hauled by two similar engines of 60 tons, 2 000 H. P., in symmetrical traction. The rear engine pushes or holds back the train, always sharing the work with the front engine.

The very satisfactory experience of several years has dissipated the fear, which was entertained at the commencement, of violent jerks in the middle of the train. In starting, accord of movement is sufficiently well secured by whistle signals, or by the movements of the couplings; during running, each of the drivers is kept informed as to the working of the other engine by the readings of his own ammeter.

These readings, however, demand continuous attention, which it would be difficult to ensure on a very long journey.

It is certain that constant communication between the engines will appreciably improve multitraction, by facilating the starting operations, and above all by transmitting without delay to the auxiliary engines a signal to stop given by the front driver.

This liaison, naturally, must be assured apart from the presence on the train of special wires. The experiments being carried out by the Orleans Company are already sufficiently advanced to convince its engineers that they will obtain satisfactory results by employing an alternating current of high frequency, superimposed on the continuous circuit of the motor circuit.

In the case of the Orleans Company the connection between engines will have another very interesting result. This Company already possesses the continuous brake on a quarter of its goods wagons (15 000 out of 60 000). In the case of goods trains on the principal lines with moderate gradients the practice is to group at the front of the train 6 or 7 wagons fitted with the continuous brake, under the control of the driver, thus giving him control over slowing up and stopping.

Such a grouping is equally practicable at front and rear of trains with a locomotive at each end and the two drivers, with this braking additional to that of their own engines, will be able, thanks to the permanent connection, to stop the train, even in the event of a break-away, without having to resort to the hand-brakes. We shall thus realise, some years in advance, the advantage of continuous braking, i. e., increased safety, greater speed, reduced personnel.

The most important advantage, which will still remain after the adoption of the continuous brake, is that to which we have referred, *viz.*, the increased haulage capacity of trains, and, consequently, of the railways as a whole. American trains have couplings of a strength of 125 tons, whereas the Berne Conventions require for wagons on the railways which they control a strength of only 30 tons. The French Companies are actively pushing forward the strengthening of their couplings up to a 70 ton limit : but many recent 55 ton couplings will remain in use for a long time, and our trains will continue to receive foreign couplings of 30 tons. If American Companies frequently resort to multitraction in order to double, treble (or more) the load of their trains, how much more should we desire to adopt it in France, to free ourselves from the load limit imposed by couplings which have only a quarter the strength of American couplings, and which for an indefinite time to come will at most amount to one-half? The absence of the continuous brake and the weakness of our couplings make it even more desirable here than in the United States to adopt a system of electrification which will allow the full use of multitraction. It may be affirmed that for those of our lines which have gradients of 10 per mil or more, electric traction will supply the most economic solution, when we arrive at the point when the development of traffic will, if steam traction be retained, necessitate the doubling of the permanent way, or the construction of relief lines.

We will only add to the preceding observations one simple remark. In those countries, like Spain and France, in which the system of reversing the steam locomotives is adopted for braking trains in descending long slopes, it has long been known that running with closed up buffers is a complete guarantee of safety. It is the same in the United States where huge trains climb gradients with several auxiliary engines pushing in the rear. But in certain countries of Europe it was held, on purely theoretical grounds, that it was necessary to avoid with the greatest care the closing up of buffers, and for this reason the reversing of the locomotive was not permitted, the rear of trains being braked when descending gradients. In several of these countries it is already, or will eventually be, the practice in the case of electric trains, to slacken speed on inclines by regenerative or rheostatic braking, which involves running with buffers closed up. In other countries the practice is to run suburban trains with a singe motor-coach pushing in the rear. Electric traction has, therefore, overcome a theoretical prejudice which the system

of reversing the locomotive could not uproot.

3. *Independence and multiplicity of driving-axles.* — Continuous current like single phase readily lends itself to the multiplication of independent driving axles from which two advantages, very valuable in the case of heavily curved lines, follow.

The distribution of the total load over a larger number of axles reduces the weight on each axle and the stress on the permanent way, and by driving the axles independently any necessity for mechanical couplings is eliminated so that the axles can be arranged in such groups as give the greatest flexibility to the locomotive without diminishing its stability, thus enabling it to readily negotiate sharp curves.

There follows from this flexibility a reduction in engine resistance in passing round curves and consequently in wear and stress alike of tyres, permanent way and steel bridges, with resultant reduction in repair costs; the necessity for strengthening up bridges is also avoided.

4. *Regenerative control.* — Dr. Wyssling, reporter to the Berne Congress for Switzerland, France, Italy, etc., had contested the utility of recuperation. His successor for Switzerland at the Rome Congress recognises its advantages and indicates further that the single-phase current system has indeed benefitted by it. It is not, therefore, necessary for us to insist on the advantages of this aspect of electric traction. We may remark, however, that its only application hitherto had been in the three-phase, single-phase and continuous current systems, and that in connection with the latter it presents an interesting consideration.

Whereas in the three-phase systems regeneration is only obtained at the normal speed, with continuous current it adapts itself to all speeds, between the maximum fixed by the conditions of the line and of the train and a minimum which is as low as 7.5 miles in the Rocky Mountains; an elasticity of great value in regulating the running of trains over heavy grades.

This ability to regenerate over a range from high to low speeds is particularly advantageous in connection with trains not fitted with continuous brakes, for instance by this means the Orleans Company has been able to considerably reduce the amount of hand-braking.

Italian experience shows clearly the weak point in regeneration at uniform speed in trains not provided with the continuous brake : loaded trains at Genoa and Mont Cenis climb gradients of 30 and 35 per mil. at speeds of 28 and 31 miles, and empty trains descend them at half this speed to the detriment of the use of the line. This is because regeneration does not take place during stopping. One would have to increase excessively the number of brakemen if descents were made at the maximum speed.

5. *Consumption of energy.* — On the Rocky Mountains line the average consumption shown by several years' working is 43.8 kilowatts-hours per 1 000 miles ton hauled, the energy being measured at the sub-stations. It is 40.5 kilowatts-hours for goods trains, and 64.1 for passenger trains, the tonnage of which only reaches one-sixth of the total tonnage. The monthly average load factor is 60 per cent of the available power, which is 25 000 kilowatts a maximum not exceeded.

The current is supplied to the railway by the Montana Power Company, which produces it in hydro-electric works, and

distributes it at 100 000 volts : the quantities consumed can therefore be exactly ascertained.

It is transformed in sub-stations situated at intervals of 31 miles which distribute from 2 000 to 3 000 kilowatts, and in exceptional cases 4 000, whilst the staff does not exceed three men.

The consumption of energy per ton mile is very low, lower than that of any other line of similar gradients. The total consumption and the load factor must be considered as still more favourable, if account is taken of the conditions under which the line is worked. The annual tonnage of 10 million tons per mile is carried by a small number of heavy trains : there are each day two transcontinental expresses of 700 to 900 tons, and three or four goods trains of 2 500 to 3 000 tons. The sub-stations, situated at intervals of 31 miles, are therefore, submitted to very varied loads, when in their section a train of 3 000 tons passes from an ascent of 15 to 20 per mil. on to an equal descent, and regeneration starts.

The line carries miscellaneous goods and a little mineral traffic : the trains are, therefore, long for their load. There is little difference between the traffic in the two directions : the tonnage on the up grade is, however, greater than the tonnage down.

Finally, during nearly 5 months of the year, an extremely rigorous winter increases the rolling stock resistance.

6. *Upkeep.* — Before electrification, the 435 miles of the Rocky Mountains line had available for their steam locomotives 5 depots and 3 workshops, of which Deer Lodge was the principal. Electrification has led to the closing of 2 depots and 2 workshops : all repairs are now concentrated at Deer Lodge, of which they only utilise a part. The shop employs 275 workmen, of whom 18 only are electricians : not only do they suffice for the complete upkeep of the 42 electric locomotives; they also carry out general repairs of 15 to 17 steam locomotives, sent there from other sections.

This result is very remarkable having regard to the importance of the traffic dealt with and to the difficulties of the line.

The engineers of the mission, who are well acquainted with the question of the upkeep of engines, knew that in the visit to the American workshops, they would find the most reliable means of comparison of the different systems. The work in the shops is a criterion : by it one may make a comparison of the locomotives and appreciate the whole organisation of traction.

It was really in the final visit to the workshops at Deer Lodge that the engineers realised that the high tension continuous current system with regenerative control was the one most suited to their requirements.

7. *Distribution of energy.* — The use by the Companies of a primary three-phase 50 periods distribution, that of the national system, would offer such an advantage that they would adopt it in any case, even were the traction current alternating at 16 or 25 periods.

The hydro-electric stations of the three Companies will be considerable distances apart, and will be surrounded by other stations. The development of traffic is the first object of every transport company, and the diffusion of energy is perhaps the most efficacious means of contributing thereto. By merging their individual distribution in the general distribution, the Companies will contribute powerfully to this diffusion. They will find there, further, a better investment,

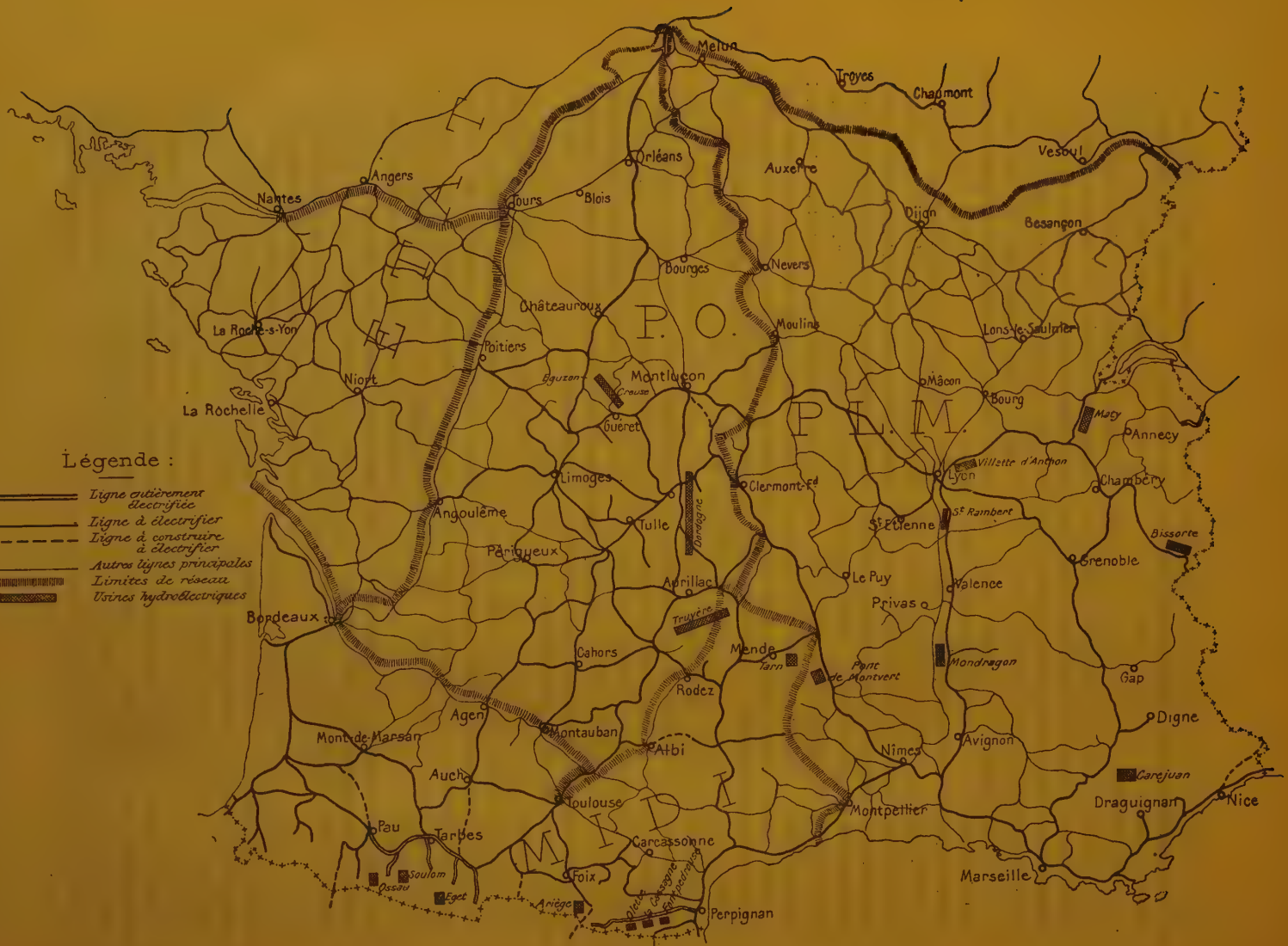

Fig. 1.

Explanation of French terms : Légende = Reference. — Ligne entièrement électrifiée = Line entirely electrified. — Ligne à électrifier = Line to be electrified. — Ligne à construire et à électrifier = Line to be constructed and to be electrified. — Autres lignes principales = Other main lines. — Limites de réseau = Boundaries

and favourable conditions for supplementary purchases or exchanges of current.

Let us consider from this point of view the situation of each of the three companies :

The Midi Company already has 4 power stations in the Pyrenees; when it has completed its present programme it will have available a total power of 250 000 kilowatts. It will partially equalise the load on the power stations in the Pyrenees by utilising lakes or by constructing reservoirs fed by water courses of considerable volume. It will probably construct several stations in the Cevennes to feed the northern part of its system, and will perhaps participate with the two other Companies in the development of the Truyère works, the special rôle of which will be explained later.

The Paris-Lyons-Mediterranean will find its principal sources of energy on the upper and middle Rhône, at spots which are not yet finally decided upon. The intention is to harness several high falls in the Alps and the Cevennes which can give a regular supply and possibly also to participate in the Truyère works.

The Orleans Company obtained in 1920 the concession of 7 hydro-electric power stations on the Haute-Dordogne and its tributaries, in the centre of its system, 250 miles from Paris and 170 from Toulouse. Their capacity will exceed 150 000 kw., double the average power, which will be completely equalised by reservoirs of more than 8 229 million cubic feet. Constructed on granite and fed by very pure water, these reservoirs will be watertight and will not silt up. The Company also has taken an important part in the concession of dams on the Creuse, 205 miles from Paris, which will be able in a normal year to produce 150 000 kw.-h. not spread equally over the year. Their working will be linked up with a steam power station of 200 000 kw., in course of construction at Cennevilliers, near to Paris. Finally, the Company will find, to the south of the Massif Central, other hydro-electric works, in construction or projected, in which it will be able to participate, in particular those of the Truyère.

The Truyère, principal tributary of the Lot, receives the waters of a watershed of 927 square miles in the south-east angle formed by the Cevennes and the Monts d'Auvergne. The average power obtainable exceeds 200 000 H. P., the supply being almost regular. The surrounding region possesses no industries; all the energy produced will have to be carried to a distance. The flow of the watercourses of the Central Plateau is complementary to those of the Alps and Pyrenees; the Truyère will feed the Rhone and Garonne basins during the winter, and the Central region during the summer.

This large programme of the organisation of hydro-electric energy shows clearly the obligation imposed on the three Companies of associating themselves in a work of unification required in the national interest and to promote the linking up of the three great producing districts.

In the case of the Orleans Company, for example, its participation in the combined scheme will have the effect of enabling the water power of central France to be transmitted first into the middle Loire district and then to Paris and the neighbourhood. It will also give the whole group of water power stations, in the dry years, the valuable assistance of a large steam power station, where economical generating is assured by the heavy and regular Paris demand.

Choice of 1 500 volts pressure. — At first the Electrification Committee contemplated the adoption of 2 400 volts pressure, but it afterwards fixed its choice on 1 500 volts as a result of detailed investigations which showed that the expense would be practically the same for the two pressures on some fairly different types of lines. This results from the close network of lines of the system to be electrified, which justifies a much closer spacing of sub-stations than that of the long isolated Rocky Mountains line.

In lowering the pressure to 1 500 volts one reaches the upper limit compatible with the use of the third-rail, which in addition to its intrinsic advantages, has the additional advantage in the case of France of replacing imported copper by French steel.

It can be employed in the particular cases in which it is found preferable to the overhead conductor.

The type of third-rail, which must be common to all the railways, has not yet been decided upon.

On its newly electrified suburban sections the State will use a special section having the contact surface under an upper flange.

II. — SPAIN.

The only other country from which we have received a positive reply is Spain.

1. *Southern Railway of Spain.* — In 1911 this Company adopted electric traction, by three-phase current, 5 200 volts, 25 periods, on the section of 14 miles, from Gergal to Santa Fé, which is a continuous grade with a maximum of 28 per mil. The weight of trains is 150 tons up, and 450 tons down the grade; the section is always covered simultaneously by one train ascending and another descending, meeting in the middle. The speed has been increased by electrification from 7.5 miles to 15.5. The locomotive is formed by coupling two vehicles each with two driving-axles, this gives four motors of 220 H. P. each.

The expenditure of energy is insignificant : the steam power station of 700 H. P. is scarcely required to furnish any energy except at starting.

2. *Northern Railway of Spain.* — In the Asturias, on the line from Leon to Gijon, the section between Busdongo and Pola de Lena, 34 miles long, descends for 3 100 feet, by a continuous slope of 20 per mil. passing through 67 tunnels, 5 of which are more than 1 100 yards long. The coal traffic which passes over this slope is limited to 4 500 tons a day, because only 14 trains are available and because the use of auxiliary engines in the rear is rendered difficult by the defective ventilation in the tunnels, and it is therefore only possible to use a single engine. The Company estimates that the electrification which it has decided to undertake will cost less than the doubling of the permanent way, and less even than the provision of extra loops; it will make it possible to increase the daily coal traffic to 12 000 tons by the increased power of the engines and above all by the systematic use of multitraction.

The system chosen is that used on the Rocky Mountains, *viz.*, 3 000 volt continuous current, with regenerative control. The present trains are fitted with the continuous vacuum brake.

The Company will generate part of the current at the mines, using coal of inferior quality, and will buy the remainder at hydro-electric stations in the district.

The electric locomotives will have six 13 ton axles, grouped in two 3-axle bogies,

each fitted with a 265 H. P. motor. It will be able to haul 427 tons with a single engine on a rising gradient of 20 per mil. at the speed of 22 miles.

In the two examples which Spain affords the object of electrification is to increase the capacity of lines having considerable traffic and difficult gradients. For the first, which is isolated, three-phase current was chosen; it afforded a satisfactory and in this case no doubt the most simple solution; we suppose that the high tension continuous current system was preferred in the second case because this line is part of a large railway system, of which other sections will eventually be electrified, for which a more elastic system than the three-phase will be preferable.

Economic results.

Most of the cases of electrification in France were effected in conditions such that it is impossible to estimate their economic effect. We have referred to the line between St. Georges De Commiers and La Mure, in the case of which it has been possible to make a comparison of expense showing a saving on working costs of 30 per cent.

The suburban electrifications have coincided with the opening of new lines, making impossible any comparison between the two systems of traction. The mountain lines have been electrified from the time of their construction, and can be compared with no other line on the same railway worked by steam. The excessive and unstable prices of the present day also would suffice to prevent a reliable estimate of the economic value of electrification.

In reality it is by other than economic considerations that the Companies will be guided in their choice of the first lines to be electrified. They will begin with those lines, the electrification of which will give an urgently needed increase of capacity, which would be more dearly bought by the ordinary processes of development.

When we lay down new permanent ways, large sidings, engine depots, we do not do so in the hope of getting an immediate return on the capital expended, but to cope with the increase of traffic, or perhaps to promote it.

It will be the same with our first electrifications. These will supply us with exact data as to the cost and result of the operations, which will then serve as a guide in the extension of the process to lines whose electrification is not demanded by any exigencies of working.

CONCLUSIONS.

The value of the different systems of electric traction is essentially relative: it varies in different countries, and on different railways in one and the same country. To-morrow it will no longer be what it is to-day. The Spanish and French Companies who have adopted high tension continuous current have done so because they believe they will find it to be the system which for the moment best satisfies their working conditions : they do not claim that it is the most perfect in itself, or that it is desirable that it should be adopted everywhere.

Better systems which may be discovered in the future will not be able greatly to improve the general results, in view of the very high efficiency of the motors and transforming apparatus which we shall employ.

We consider that the Congress has only to record the communications which will be made to it by the different countries, and to realise that it is at present impossible to recommend the adoption of a single system, and that even were unification possible, its advantages would only be insignificant.

16 August 1921.

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REPORT No. 3

(America)

ON THE QUESTION OF THE NET COST. RATES (SUBJECT XIII FOR DISCUSSION AT THE NINTH CONGRESS OF THE INTERNATIONAL RAILWAY ASSOCIATION), (1)

By Samuel O. DUNN.

The American reporter upon this question for the Congress which was to have been held in Berlin in 1915 was Mr. Fairfax Harrison, President of the Southern Railway. Mr. Harrison prepared a report which was published (2), and which covered thoroughly the history of the efforts which had been made in the United States up to the year 1915 to devise means of ascertaining the net costs of transporting freight and passengers by railroad. In his report he described luminously the operating and transportation conditions which make it so difficult to ascertain the costs of transporting passengers and freight on any individual railroad; which make it more difficult to devise any formulae by which these costs can be ascertained on more than one railroad; and which have thus far rendered it impracticable to arrive at costs which can be used except in a very general way as a basis for fixing rates.

Mr. Harrison's report covered so fully the whole subject of cost accounting as a basis for rate making so far as it had been developed in this country up to the time he wrote that I shall only try to supplement his report and bring the record up to date.

1. Allocation of Operating Expenses as between the Freight Service and the Passenger Service.

As Mr. Harrison stated in his report, the Interstate Commerce Commission in March, 1914, issued a tentative classification (Statistical Series Circular No. 3) of operating expenses incurred in passenger and freight train service which was intended for discussion and study. In May of that year it held hearings upon the subject, after which it decided to establish a system for the allocation of freight and passenger train expenses at the earliest practicable date. In March 1915, it issued a revised tentative scheme for the separation of expenses (Statistical Series Circular No. 4) which gave formulae for the division of most expenses, but which suggested no plan for the division of maintenance of way expenses. The Commission was helped in devising the formulae used by it by a special committee of railway officers, but the commission explained in its circular that these railway officers did not recede « from the position which the (railway) accounting officers had previously taken, namely, that no uniform basis could be

(1) This question runs as follows : « Determination of net cost of carriage (passengers and goods), taking capital charges into consideration. Its relation to rates charged. »

(2) *Bulletin of the Railway Congress*, number of September-October 1914, p. 857.

adopted which would apply equitably under all conditions ».

At hearings on the Commission's plan held in May 1915, the discussion related chiefly to four bases for apportioning maintenance of way expenses which had been suggested for consideration and which were as follows :

1° The locomotive ton-mile;
2° The locomotive tractive-power mile;
3° The direct charges;
4° The gross ton-mile.

Most of the representatives of the railways advocated locomotive ton-miles as the best basis of apportionment. Under this plan maintenance of way expenses would be divided between passenger and freight train service according to the weight of the locomotives used (exclusive of tender) multiplied by the miles they travelled. It takes no account of the weight of the train behind the locomotive. Most of the representatives of the state railway commissions advocated use of the basis of gross ton-miles. This method ignores the locomotive entirely, and takes into account only the total weight of cars and contents multiplied by the distance they travel.

When the Commission issued its final order on 15 June 1915, it stated it had been unable to decide between the two methods. « The disputed part of the expenses, » it said, « will be required to be reported as undivided. Carriers will be required to compile locomotive ton-mile data and the relative merits of locomotive-ton-miles, direct charges estimated gross ton-miles, or modifications thereof can be further considered with the aid of statistics thus made available ».

The Commission divides the railways into three classes, all those which earn more than $1 000 000 gross annually being included in Class I. Only the Class I railways were required to report their expenses divided in accordance with the commission's formulae.

Professor William J. Cunningham, James J. Hill, Professor of Transportation at Harvard University, gave a very concise but luminous summary of this plan of the Commission for the separation of operating expenses in an article in the *Quarterly Journal of Economics*, February 1917. I cannot do better than quote Professor Cunningham's summary, which is as follows :

Briefly, the Commission, while avoiding extreme particularity in its instructions, lays down the general principles that :

1° Such expenditures as may be definitely and accurately allocated should be reported separately;

2° Such expenditures as may not be definitely and accurately allocated, but which are susceptible of apportionment on some basis which will approximately represent the facts, should be pro-rated;

3° Such expenditures as those which defy any accurate or even any approximate allocation or apportionment should be reported as « undivided » the Commission to determine later, or as needed in special cases, how the undivided items should be split between the two classes of service.

The three divisions, then, are :

a) Direct charges;

b) Indirect charges susceptible of approximate separation;

c) Overhead or other joint costs which are very difficult to separate.

In the first group are the wages of the locomotive and train crews, the cost of locomotive fuel, the maintenance of motive power and other rolling stock, the charges to freight claims and baggage claims, and other minor items of expense which may be kept entirely distinct by classes of service.

In the second group are such accounts as station service, which may be directly allocated in a large part, the remainder

to be divided in proportion to « man hours » in each class of service; yard service, directly allocable in part, the remainder to be separated in proportion to « locomotive hours » in each class of service.

In the third group are most of the items under maintenance of way and structures, such as roadway maintenance, the renewals of rails, ties and ballast, and the maintenance of work equipment. It includes as well all items classified as general expenses.

Throughout the maintenance of way group, which presents the most difficult problems in apportionment, the Commission requires that under each account such expenses as may be directly traced or recorded should be charged either to the freight or to the passenger service, the remainder to be regarded as joint expenses and reported as undivided. Superintendence, for example, is to be reported as undivided. With respect to maintenance of station buildings, the rules require that carriers keep a record of maintenance costs of freight stations (to be charged to freight) and of passenger stations (to be charged to passenger) and that the remainder should be pro-rated in the same proportion as the direct charges to that account. All roadway and track expenses, with the exception of yard track maintenance (which is to be recorded separately and divided between freight and passenger in proportion to switch locomotive miles in each class of service) and maintenance of roadway buildings, are to be reported as undivided. Maintenance of water and fuel stations is to be divided on the basis of the freight and passenger proportions of fuel costs. Maintenance of shops and engine houses is to be divided in the proportion which the freight and passenger services assume in the total charges to the maintenance of equipment group of expenses. The cost of maintaining grain elevators, storage warehouses, and the like, is to be assigned directly or apportioned according to the facts in individual instances. The maintenance cost of telegraph and telephone lines, and of signals and interlockers, is to be divided on the basis of transportation train miles. Power plant maintenance is to be assigned according to facts in individual instances. Maintenance cost of paving roadway, machines, etc., and the charges to injuries to persons, insurance, stationery and printing and other maintenance of way expenses are to be reported as undivided, unless a determination of facts in individual instances makes definite allocation possible. The cost of maintaining joint tracks and other joint facilities should, as far as practicable, be treated individually according to the use made of them by the reporting carrier, regardless of the use made of them by other carriers.

Under maintenance of equipment expenses one item only (work equipment — repairs, depreciation and retirements) is to be reported as undivided. The maintenance of work equipment is to be regarded as an undivided expense and should be treated in the same manner as roadway and track costs. With respect to the maintenance and replacement of locomotives and cars (other than work equipment) the railroads are required to keep their accounts in such form that the actual cost of repairing and replacing of freight locomotives and cars shall be charged to the freight service, and that the similar costs for passenger locomotives and cars shall be charged to the passenger service. In the case of locomotives used in both classes of service, the expense is to be pro-rated on the basis of locomotive miles in each class of service, altho permission is given to use « some arbitrary deemed by the carrier to be applicable, as, for example, by making one and a half passenger locomotive miles equivalent to one freight locomotive mile ». The cost of maintaining locomotives used in mixed train service is to be apportioned on the basis of car miles in mixed trains (unless the carrier is able to make a more nearly accurate estimate), and the main-

tenance cost of switch locomotives is to be divided according to the freight and passenger switching locomotive miles. For the latter account the railroads are permitted to take all yards together annually. This is essentially a « locomotive hour » basis, since switching locomotive mileage is computed on the arbitrary basis of six miles per hour, according to the rules of the Commission pertaining to the compilation of locomotive, train and car mileage.

For the charges on account of depreciation and retirements of locomotives and cars the rules require an assignment « direct as far as practicable », and an apportionment of the unassigned remainder « according to the mileage made in each class of service by the individual locomotives (or cars) or by classes of locomotives (or cars) ». In the case of locomotives alone « if this method is not practicable, then the division should be made according to the aggregate freight locomotive and passenger locomotive ton mileage of the locomotives affected for the year, or upon some other basis deemed by the carrier to be more nearly accurate ».

Charges to superintendence (maintenance of equipment), shop machinery, power plants, floating equipment, miscellaneous equipment, injuries to persons, insurance, stationery and printing, and other maintenance of equipment expenses, are to be apportioned on the same basis as the freight and passenger proportions of repairs of locomotives and cars. The same basis is to apply to maintaining joint equipment at terminals « unless a knowledge of local conditions enables a carrier to make a more nearly accurate estimate. Each terminal should, as far as practicable, be treated individually ».

The entire group of traffic expenses is to be assigned directly. This is usually practicable, inasmuch as the freight traffic department and the passenger traffic department are ordinarily distinct and separate below the executive offices. Common traffic expenses are to be apportioned on the basis of the directly assigned expenses in this general account.

In the group of transportation expenses no items are te be reported as undivided. The cost of dispatching trains is to be apportioned according to transportation train miles. The cost of station employees and station supplies and expenses is to be charged according to direct analysis, the common expenses to be apportioned as in the case of superintendence (to be mentioned later). Charges to weighing, inspection and demurrage bureaus, and to coal and ore wharves operation, are to be assigned directly. The yard group of expenses is to be assigned directly as far as practicable, the unassigned remainder to be apportioned in accordance with the freight and passenger yard switching locomotive miles of the year, each yard to be treated individually, if practicable, but at least excluding the mileage of those yards which have been treated as wholly freight or wholly passenger. In the cost of operating joint yards and terminals, each yard or terminal is to be treated individually, and a separation made according to local conditions.

The wages of train enginemen, motormen and train crews, the cost of fuel, water and other locomotive supplies, and the cost of train supplies, are to be assigned directly as far as practicable, common expenses to be divided on the basis of the direct assignments in each account. The charges to road enginehouse expense are to be divided according to the number of engines handled for each class of service, an arbitrary to be used, if deemed proper, to give freight locomotives a greater weight than passenger locomotives. Operation of sleeping cars, express service and baggage claims are to be charged direct to passenger. The cost of settling freight claims is to be charged direct to freight. Charges to signal operation and crossing protection are to be apportioned on a transportation train mile basis. The expense of clearing wrecks is to be

assigned directly, as far as practicable, according to the service in which the accident occurred and not according to the responsibility for the accident, the unassigned remainder to be divided (like superintendence) on the basis of the entire assignable items in the transportation expenses group. The charges to damage to property, damage to live stock on right of way, and injuries to persons, are to be treated the same as clearing wrecks. The remaining transportation accounts — namely, superintendence, train power purchased and produced, operating floating equipment, stationery and printing, insurance, and other transportation expenses — are to be divided according to the freight and passenger proportions of the aggregate of the assignable items in the transportation group. The cost of operating joint tracks and facilities is to be similarly treated « unless a knowledge of local conditions enables the carrier to make a more nearly accurate estimate ».

Transportation expenses of water lines, miscellaneous operations, and general expenses, are to be assigned directly as far as practicable, the remainders to be reported as undivided « unless a knowledge of local conditions makes possible a more nearly accurate estimate ».

Carriers are required to indicate the total amount of credit which should be given to the freight service for work (such as carrying company fuel and other company supplies) performed for the passenger service, and *vice-versa*.

The result of the application of this method of separation to the operating expenses of the Class I railways in 1916 was that 47.5 % of their total expenses were assigned solely to freight service and 16.5 % were found to be due solely to passenger service. In other words, 64 % of the total expenses were ascertained to have been incurred exclusively for one or the other kind of service. Of the expenses incurred for the rendering of both kinds of service, an amount equivalent to 13.2 % of the total expenses was apportioned to freight service and an amount equivalent to 5.1 % of the total expenses to passenger service. Thus, 82.3 % of the total expenses incurred were directly assigned, or apportioned to freight and passenger train service, the total expenses thus charged to freight service being 60.7 % of the total expenses and those charged to the passenger service being 21.6 % of the total expenses. (It may be of some interest in this connection to note that of the total earnings of the Class I railways in 1916, 71.5 % were derived from freight train service and 24 % from passenger train service).

The maintenance of way and structures expenses amounted in 1916 to 18 % of total operating expenses. Of this part of the expenses it was found possible to assign directly only 11.4, while 11.7 % of them were apportioned and 76.9 % were left undivided. The maintenance of way expenses which were left undivided were *13.8 % of the total operating expenses;* and since only 17.5 % of the total operating expenses were left undivided the result was a forcible illustration of the fact that it is the maintenance of way expenses which present the most serious obstacle to an approximately satisfactory division of the total operating expenses between passenger and freight train service.

Hardly had the figures from which these results were derived been compiled when the United States entered the Great War. As one means of relieving the railways of a large amount of clerical work they were authorized to refrain from apportioning the expenses common to both freight and passenger service in the years 1917, 1918 and 1919.

Effective on 1 January 1920, however, the Commission established a new method for the separation of operating expenses which in most respects was very similar

to that in effect in 1916, but which differs from it in a few very important particulars. This new method had been briefly summarized as follows by Dr. Julius H. Parmelee, Director of the Bureau of Railway Economics, in an article in the *Quarterly Journal of Economics*, February 1920.

First, all expenses directly related to the freight and passenger services are so assigned. This direct-charge method will apply to 100 of the 196 primary expense accounts, representing 66.6 %, or almost exactly two-thirds, of total operating expenses. Second, certain other expenses will be apportioned on definite bases laid down by the Commission. For example, yard maintenance will be apportioned according to switching locomotive miles, dispatching trains on the basis of transportation train miles, track maintenance on the basis of locomotive fuel cost, and so on. There are 44 of these accounts, representing 14.9 % of total expenses. Third, all other expenses are to be separated in the average proportions of other accounts in their respective group or class, as defined by the instructions. This is the basis prescribed for 52 of the 196 accounts, representing 18.5 % of total expenses. In effect, the procedure is to find the average percentage under the first two groups, namely, directly assigned charges and proportional apportionments, and then to apply that percentage to total operating expenses as a whole. So far as affecting the average is concerned, the third group of accounts play no part whatever; they are simply brought in to make the process complete.

As Dr. Parmelee says, « most important in the new classification is the adoption of the fuel cost basis for apportioning the greater part of the track and some of the other expenses in the maintenance of way groups. This is frankly a new departure, but under a test conducted by the Commission was found to produce percentages lying midway between the results under the locomotive ton-mile and the gross ton-mile bases ».

The suggestion for using the locomotive fuel consumed as the basis for apportioning most of the maintenance of way expenses between passenger and freight train service was first advanced by Professor Cunningham of Harvard University, who is an experienced railroad man as well as an authority on railway economics of very high reputation. Since the division of maintenance of way expenses presents the most difficult and vexatious problem of railway cost accounting, and since the Interstate Commerce Commission has adopted fuel consumption as the main basis for the division of these expenses, it will be well to present in Prof. Cunningham's own words his argument for the fuel consumption basis, I therefore quote as follows from his article on « The Separation of Railroad Operating Expenses » which was published in the *Quarterly Journal of Economics*, February 1917.

The theory upon which the fuel basis is offered as a substitute for train, locomotive and car miles or combinations thereof, is that it is a more scientific measure of use. Fuel consumption, in a large degree, is proportional to the horsepower developed. Horsepower is the resultant of locomotive tractive force and speed. A given number of horsepower may be utilized in hauling a heavy train at slow speed or a light train at high speed. Speaking in general terms, in locomotives of similar design, the horsepower developed is closely related to the volume of steam used in the cylinders, and the steam production in boilers of similar design is in turn closely related to the amount of fuel consumed in the firebox. There is, however, a critical point in the piston speed at which the horsepower efficiency is greatest.

Since the horsepower developed is directly proportional to the speed of the train, it follows that the fuel consumption by a given train increases somewhat in proportion to the speed of the train. Fuel consumption, however, does not vary directly with speed, yet it bears a close relation to it. It is impracticable to show the relation exactly by formula, because of the many variable factors which affect train resistance and locomotive boiler and cylinder efficiency: but the indications of many tests support the statement that as between trains of different classes on the same division, the fuel consumption, as a measure of train horsepower, automatically equates for both weight and speed. It takes account of the weight or power of the locomotive, the weight or number of cars, and the speed of the train. It affords, then, the only least common multiple yet suggested that has some claim to the term scientific.

From an accounting viewpoint the fuel basis is desirable as it requires no special compilations when (as should be done for other purposes) fuel consumption statistics are kept separate for the three classes of service — freight, passenger, and switch. The use of the locomotive ton mile basis, on the other hand, requires the keeping of special statistics for that purpose alone, and, moreover, the basis is less scientific.

The range of difference in the results obtained by using several of the bases which have been discussed, may be seen if they are applied to the maintenance of way and structures expenses of the Boston & Maine Railroad. The total charges to that group of expenses during the year ended 30 June 1915, were $7 118 602. A small part of these expenses were allocated directly, but for the purpose of illustration we will apply the several methods to the total of the entire group of maintenance of way and structures. They are arranged in the order in which they burden the charge to passenger service.

BASIS.	Chargeable to passenger service.	
	Per cent.	Amount.
Revenue train miles	60.7	$4 320 991
Revenue road locomotive miles	57.1	4 064 722
Revenue road locomotive ton miles	53.0	3 772 859
Direct charges: transportation costs only	46.8	3 331 506
Revenue train miles and car miles	40.6	2 890 152
Fuel consumption; road and switch locomotives	40.0	2 847 441
Direct charges; transportation and equipment	39.6	2 818 966
Operating revenues	39.3	2 797 611
Gross revenue train ton miles (estimated)	33.3	2 370 494
Revenue car miles	20.6	1 466 432

The difference between the charge to passenger service on the train mile basis, $4 320 991, and the charge on the car mile basis, $1 466 432, is nearly three million dollars. It will be noted that there is little difference in the results under four of the bases, *viz.*, train miles and car miles combined, direct charges under transportation and equipment maintenance, fuel consumption, and operating revenues.

The Interstate Commerce Commission has thus worked out and required the Class I railways to use a method which provides for the separation between freight and passenger train service of all their operating expenses. That the Commission itself does not regard its present method as by any means perfect is indicated by a memorandum issued by the Commission's own statistician soon after

the method was adopted, in which he said: « No one has proposed a method (for dividing common maintenance of way expenses) which can be demonstrated to be mathematically exact... To measure each one of the many influences on track expenses exactly in figures under the varying conditions existing on the roads seems a hopeless task, notwithstanding decades of discussion ». (The Commission's present rules governing separation of operating expenses between freight service and passenger service are given in Appendix I).

2. Allocation of Capital Charges to the Freight Service and to the Passenger Service.

Even though the total operating expenses could be divided with approximate completeness and accuracy between the freight train and the passenger train services, the problem of determining the net cost of rendering each class of service would be far from solved.

The total cost of rendering railroad service necessarily consists of two classes of outgo — operating expenses and capital charges. In the long run it is almost as impossible to evade paying the capital charges as to evade paying the operating expenses. If railways are owned by government, then government must pay the interest on the capital invested in them, and if it cannot be paid from the earnings of the railways it must be paid from funds raised by taxation. If railways are owned by private companies and operated without any guarantees from government they must earn enough net return to pay satisfactory interest and dividends to the owners of their securities, or they will become unable to get enough new capital to so develop and enlarge the capacity of the properties as to enable them to cope with the increasing commerce of the country. Maintenance of the ability of the railways to raise new capital is of importance in every country, but of especially great importance in a new and rapidly developing country such as the United States.

The conditions under which our railways have been constructed and developed and the interpretation which has been placed by the courts upon certain provisions of the Federal constitution, have resulted in the establishment in the United States of certain principles and methods for determining the amount of net return railways should be allowed to earn which are unlike those which have been established in any other country.

For many years there was practically no regulation, or even supervision, exercised by the Federal or state governments over the issuance of railway securities. During that long period, when the railways were being extended and developed on a scale and with a rapidity never known in any other part of the world, large amounts of stocks, and even bonds, were sold by the railway companies for less than their par value. This resulted in the original capitalizations of many railways exceeding their original costs of construction. In later years large parts of this original difference between capitalization and cost of construction were offset by improvements and additions made to the properties by the investment of earnings which could have been paid out to the stockholders as dividends. In many cases, also, bonds and stocks were sold for more than their par value and the entire receipts from their sale invested in the properties, with the result of further reducing, for the railways of the country as a whole, the difference between total cost and total capitalization. Finally, a very large part of all the railways of the United States have once or more than once in their history become bankrupt and been placed in the hands of

receivers. While being managed by the receivers they have usually had invested in them large amounts of their earnings which if they had been solvent would have been paid out as interest and dividents, and the reorganizations which have terminated the receiverships usually have involved substantial reductions of their outstanding securities.

In these and other ways the total investment in the railways of the United States as a whole has been, especially during the last quarter of a century, increased so much more than their total outstanding capitalization that while there are some individual railways which still are largely over-capitalized, it is the opinion of most persons who have carefully studied the subject that the entire investment which has been made in all the railways at present fully equals their combined outstanding capital securities.

The original over-capitalization of many railways, however, has had and is still having an important and even vital effect upon the regulation of their rates by the state and Federal commissions. The Federal Constitution forbids either a state or the national government to confiscate private property. The Supreme Court of the United States in a long series of important decisions established the principle that for a state government or the national government to fix rates for a railway which would destroy its ability to earn a reasonable net return over and above its necessary operating expenses and taxes would leave it valueless in the hands of its owners and therefore would be confiscation as prohibited by the Constitution. In the famous Nebraska Rate Case decided in 1897 the Supreme Court held that a railway was entitled to earn a « fair return upon the fair value » of its property.

This speedily raised two vitally important questions. The first was as to how the « fair value » of a railway's property was to be ascertained. The second was as to what percentage of net return upon this fair value would be a « fair return ».

The Supreme Court in the Nebraska Rate Case said that in determining what was the « fair value » of a railway various factors must be considered, including the cost of its original construction and of permanent improvements, its probable cost of reproduction, the amount and market value of its stocks and bonds, its earning capacity under the rates prescribed, etc. While the outstanding stocks and bonds were mentioned as a factor to be considered, the decision established that it was the value of the property, and not the outstanding securities, upon which a return must be allowed to be earned and that it was only as evidence regarding the value of the property that the outstanding securities could be considered.

The decision was followed by some years of discussion regarding the exact way in which the valuation of a railway should be made as a basis for determining what rates it should be allowed to charge. The *market* value of any property — its value from the standpoint of its owner and from the standpoint of any body who may wish to buy it — is determined mainly by its net earnings. It was argued, however, that a valuation of the railways could not be based on their net earnings since their net earnings resulted from the rates charged by them and the very purpose of valuation was to determine whether these rates and the net earnings that resulted from charging them were reasonable. Some contended that the valuation should be based mainly on what the railways had actually cost, and others that it should be based mainly on what it would cost to reproduce them at the present time.

Beginning about the year 1906 several

states made valuations of railways within their own borders. The state commissions had no authority to regulate any rates except those charged for freight hauls or passenger journeys which began and ended within their own states. Therefore the state commissions tried to determine what part of the value of the railways was assignable to the transportation service rendered entirely between points within the state.

The valuations made by the state railroad commissions and the commissions' attempts to apportion the value found between the interstate and intrastate business led to litigation which resulted in the decision of the Supreme Court of the United States in the Minnesota Rate Case, mentioned by Mr. Harrison in his report. The valuation in this state was based almost entirely on the estimated cost of reproducing the railways. The investigations in Minnesota and other states made clear that for various reasons it was impossible to ascertain even approximately what most lines of railway had cost. The courts in several instances refused to uphold the methods of valuation used or the apportionments made of the value found as between state and interstate business. In consequence there was increased agitation of the subject until in 1913 Congress passed a law directing the Interstate Commerce Commission to make a valuation of all the railways of the United States and to apportion the value of the railway properties as between the states. The express purpose of this valuation, like those made by several of the states, was to establish a basis for determinig what net return the railways should be allowed to make and what rates they should be allowed to charge.

The Commission has now been engaged for over seven years in collecting data with which to make its valuation of the railways. The valuation law, under which it is doing the work, mentions several factors such as the original cost of construction and the cost of reproduction which it must consider, and directs it also to consider any and all other factors which it believes should be given weight. The « tentative » or preliminary valuations of a number of individual railways which the Commission has made public show that it has given principal and indeed almost exclusive weight to two factors. The first is the value of the land owned by the railways, which is assumed by it to be practically the same as the value of adjacent land owned by other persons and concerns. The second is what it would cost to reproduce the other physical property of the railways at the wages and prices which prevailed in 1914, with a deduction for such depreciation as has occurred in the various elements of the property since these elements were new.

Some of the most important principles which should be applied in determining the mere « physical value » of the railways are still in controversy. Furthermore, the railways entirely reject the view that only the tangible properties should be considered. They contend, for example, that each railway has a « going value », that the going value of some railways is much greater in proportion to their «physical value» than that of others because the total traffic that they handle and the net earnings that they can make on any basis of rates are larger; and that these differences in going value as well as the differences in physical value should be considered in arriving at the total valuations of the various railways.

The Commission expects to complete its valuation of all the railways within the present year. Even, however, if its findings should be accepted by the railways or upheld by the courts the problem of relating railway freight and passenger

rates to capital charges would still be very far from solved. If the valuation is to be made a really practical basis for regulation of rates it must be apportioned in some way to the freight and passenger business. Now, this will be an even more difficult task than that of dividing operating expenses between freight and passenger business. There are, of course, certain important parts of a railroad's property which are provided solely to handle one or the other class of business and the valuation of which can readily be assigned to that class of business. Passenger cars and locomotives and passenger stations are provided solely to handle passenger business. Certain shops and their equipment are provided solely to repair and maintain passenger cars. Certain yards are provided solely for the storage of passenger cars.

It happens, however, that very much the largest part of a railroad's investment and physical value is represented by lands, roundhouses, roadway, tracks, yards, water and coal handling appliances, signal apparatus and other permanent structures which are provided and used constantly for the rendering of both freight and passenger service. These are the parts of the property the cost of whose maintenance is charged to the « maintenance of way and structures » account. We already have seen that it has been found practically impossible to devise any approximately satisfactory method of apportioning the cost of maintenance of way and structures to the passenger and freight services and that this has been the greatest obstacle to devising any satisfactory method of dividing the total operating expenses between freight and passenger service. While, however, the cost of maintaining the roadway, tracks and other permanent structures is a comparatively small part — only 18 % — of the total operating expenses, the value of these parts of the property is a very large part — probably three fourths — of the entire value of the physical property. While the Interstate Commerce Commission had not completed its valuation of all the railways, the Transportation Act, which went into effect on 1 March 1920, authorized and directed it to use such information regarding the value of the properties as it already had obtained in its inventorying of them as a basis for the regulation of rates until it had completed the entire valuation. In its decision authorizing large advances in rates on 26 August 1920, the Commission estimated the entire valuation of the Class I railways at $18 900 000 000. The « property investment » shown by the books of the Class I railways at the time was approximately $19 100 000 000.

While the Commission thus made a preliminary valuation about equal to the investment in the properties shown by the companies' books, and while it granted large advances in both freight and passenger rates, it made no attempt whatever to assign the values found to the freight and passenger services.

After much consideration of the subject I have been obliged to reach the conclusion that no method based upon definitely ascertained facts and conclusions reasonably drawn from them ever has been or ever can be devised by which the investment in or the value of a railway can be apportioned satisfactorily between its freight and passenger service. Most of the investment has been made to render both kinds of service. On the other hand most of the investment would have had to have been made to have renderd either kind of service. Perhaps as reasonable a method as any of assigning property values and capital charges to freight and passenger service would be to make the most complete separation possible of the operating expenses, and then apportion to

each service a percentage of the capital charges equal to the percentage of the total operating expenses assigned to it.

3. Apportionment of Railway Operating Expenses and Railway Values to State and Interstate Traffic.

As Mr. Harrison said in his report, the regulation of railway rates in the United States is vested in both the Interstate Commerce Commission and various commissions representing the states. The former regulates interstate rates while the latter regulate the rates charged for the transportation of freight and passengers moving wholly within a single state. Formerly state authorities made rates for transportation within the state in almost complete disregard of the rates fixed by the railways themselves or by the Interstate Commerce Commission on interstate traffic — that is traffic moving between or through two or more states. This rendered it necessary for the railways on the one hand and the state authorities on the other to attempt to divide railway operating expenses and values not only as between freight and passenger service, but also as between intrastate and interstate traffic. There is nothing I care to add to what Mr. Harrison said regarding cost accounting and the making of rates as affected by this necessity for arbitrarily dividing railway operating expenses and values between state and interstate traffic, further than to say the situation has been somewhat changed since he wrote his report. The freedom of the state commissions in regulating state rates has been somewhat abridged by certain provisions of the Transportation Act which went into effect on 1 March 1920.

4. Relationship of Net Cost to Rates Charged.

The difficulties of dividing all operating expenses between passenger and freight train service satisfactorily have been found to be very great and in the case of some kinds of expenses, especially those of maintenance of way, practically insuperable. The difficulties encountered in apportioning railway values or capital charges to the two kinds of service are even greater, and as to the larger part of the values or capital charges are insuperable except by the use of hypotheses whose relationship to the real facts, if the facts could be ascertained, might be found to be very remote. When to these difficulties are added the difficulties encountered in efforts to apportion the operating costs and capital values for both the freight service and the passenger service between state and interstate business, the figures for the net costs of all the interstate and intrastate freight business handled and for all the interstate and intrastate passenger business handled are likely to depart widely from what the facts would be found to be if they were ascertainable. When, finally, attempts are made to assign these costs for passenger and freight service, and for state and interstate service, to all the millions and even billions of services rendered by the railways in the transportation of mail, express and passengers upon passenger trains for the most widely varying distances, and in the transportation in freight trains of literally thousands of different commodities for the most widely varying distances — all the traffic being handled under topographical, traffic and operating conditions affording combinations of conditions which are never exactly alike on any two railroad divisions, which often are widely dissimilar on adjacent divisions of the same railroad, and which are utterly different, for example, on mountain lines with a thin traffic and on water lines with a dense traffic — the resulting figures are not only sure to vary in the most

extreme manner, but they are also pretty sure to show nothing except what every student of railway affairs already knows, namely, that the total costs of rendering even similar railway services vary widely under different conditions and that the costs of rendering different railway services under different conditions vary in the most extreme manner.

Suppose, however, that the operating expenses and the capital charges assignable to every single service rendered by the railways of the United States could be accurately ascertained. Of what value would the information be in making rates?

The total earnings of each individual railway, and of the railways of a country as a whole, should be sufficient as an annual average, assuming reasonably economical management, to pay all expenses and the normal rate of interest on the investment. If a railway owned by a government earns less than this it will incur a deficit which the taxpayers of the country will have to pay. The burden imposed upon the country's industry and people will be just as great as if the total cost of the enterprise were covered by the passenger and freight rates charged, but the burden will be less equitably distributed. If a railway system owned by private investors does not earn enough to pay at least its operating expenses and the normal rate of interest on the investment in it the service will become poor and inadequate. Regardless of the ownership of the railways the total rates should be sufficient, on the average, to cover all costs, operating and capital.

But 1° making the rates charged such that the earnings ordinarily would cover all costs, and 2° making the rates so that the rate charged for each separate service rendered would be equivalent to the total costs incurred for that service, would be two entirely different matters even if the costs of each service could be accurately ascertained. We know enough about railway costs to know this, even though no perfect system of cost accounting has as yet been devised.

First, the total costs of rendering each and every service rendered vary from month to month, and even week to week, owing to constant fluctuations in the total volume of traffic. For example, the total capital charges of an American railway are the same in May of each year as in October, but the freight handled is almost always substantially smaller in May than in October, and consequently the amount of capital charges assignable to each unit of freight service rendered in October almost always is smaller than in May. To make the rates accurately correspond with the costs, it would be necessary to change the rates with every seasonal fluctuation in the traffic.

Second, costs vary substantially on different parts of the same railway. They are higher per ton per mile on a division with an average density of, say, 1 550 000 ton-miles per mile of line than on the very next division, which may have an average density of 4 000 000 ton-miles per mile of line. If rates were to be actually adjusted to costs, it might be necessary to make them much higher on, say, fifty miles of the line of a railway than on the very next fifty miles of the line of the same railway.

Third, in the United States railways owned by different companies parallel and compete with each other. The total costs for rendering similar services differ widely on these different railways owing to differences in their length between the same points, in their gradients and other physical and operating conditions, and in their densities of traffic. If rates were to be adjusted accurately to total costs it would be necessary to make different

rates for similar services rendered by these different railways in handling competitive traffic. But if the railway having the lowest costs charged lower rates than any of the other railways, it would capture all of the competitive business.

The extent to which readily ascertainable operating costs vary on railways operating under different conditions, although often in close proximity to each other, is illustrated by certain unit cost figures for the railways of the United States in the first eight months of 1921, which were compiled by the Interstate Commerce Commission. The Commission divides the railways into eight differents regions. The unit costs given for the railways of these eight regions were the costs per 1 000 gross ton-miles (excluding locomotive and tender) of Locomotive Repairs, Engine-house Expenses, Enginemen's and Trainmen's Wages, Fuel and Other Locomotive and Train Supplies. These selected costs, for the period mentioned, were as follows :

Pocahontas Region	$1.025
Great Lakes Region	1.205
Southern Region	1.292
Ohio, Indiana, Allegheny Region	1.302
Central Western Region . . .	1.323
Northwestern Region	1.396
Southwestern Region	1.398
New England Region	2.09

It will be noted that these selected items averaged only $1.025 for 1 000 gross ton-miles in the Pocahontas Region, and that in all other regions they averaged 20 to 100 % higher.

Fourth, the values per ton of different commodities vary widely, and such knowledge of operating costs as we have makes clear that there is no close relationship between the costs of handling different commodities and the rates that they can bear. Therefore, if the rates on different commodities were accurately adjusted to the costs of haulage as far as the costs are ascertainable, many kinds of commodities would be barred from transportation by railroad.

This is as true of passenger traffic as it is of freight traffic. A workingman cannot afford to pay as high passenger fares as a millionaire. A ton of sand cannot bear as high a rate as a ton of anthracite coal and a ton of coal cannot bear as high a rate as a ton of silk. Suppose the railway ascertained the exact total cost, including all operating expenses and capital charges, of hauling a ton of sand a certain distance and tried to apply to it an equivalent rate. Probably the sand could not bear the rate and the railway woult not get the work to haul it. It would thus fail to increase its business by that much and to take advantage of the opportunity to reduce the cost of handling every unit of its traffic by thus increasing the total traffic handled. The handling of the sand would increase the railway's total expenses by a small amount. Suppose the railway made a rate on sand which was less than the total cost theoretically assignable to it, including all capital charges, but which was more than the amount which the handling of the sand *added* to the expenses which it was previously incurring, and on which the sand could move. The result would be that the total earnings of the railway would be increased more than its total expenses and it would make a profit by handling the sand in spite of the fact that it would be handled for less than the « total cost ».

I have mentioned already what seems to me the fundamental principle of ratemaking. This is, that the rates as a whole of individual railways, or of a group of railways, operating in the same territory should be so made that the total earnings resulting will cover all costs, including operating expenses and capital charges.

The foregoing illustration regarding the making of rates upon sand brings up a principle of rate-making of hardly less importance. This is, that if any traffic can bear a rate greater than the amount by which the handling of the traffic will *increase the carrier's total expenses*, then the rate should be made regardless of how far short it may fall of covering the total costs, including capital charges, which, under even the most perfect method of cost accounting, might be assigned to the particular service of handling this particular traffic. Now, the additional cost of handling additional traffic usually, and, indeed, almost always, is easily ascertainable with approximate accuracy.

If, however, some traffic must be carried at rates obviously much less than the total costs which would be assigned to it if all operating expenses and capital charges were considered, it necessarily follows that some traffic must be charged rates much in excess of the total costs, operating and capital, that a perfect system of cost accounting would assign to it, or the rates as a whole will not produce earnings sufficient to cover the operating expenses and capital charges as a whole. Now, it is conceivable that if every cost entering into the rendering of every individual service rendered by a railway could be ascertained, the rates might be so adjusted that traffic which could bear only *additional* costs would be charged rates accurately representing *additional* costs, that traffic which could bear only average costs would be charged rates which would accurately represent average costs, and that traffic which could bear rates much higher than average costs would be charged rates accurately representing the total costs that it could stand. But upon what principles would such a scheme of rates actually be based? It might be said to be based upon the accurately ascertained costs of rendering the different services, but, in fact, it would be based upon two simple but fundamental principles upon which every system of railway rates that ever resulted in developing a large traffic upon prosperous railways was based, namely : 1° The principle of « charging what the traffic will bear », and 2° the principle of establishing schedules of rates which, as a whole, would produce earnings that would cover all operating expenses, interest upon the investment, and, if possible of attainment, some profit over and above interest in the investment.

The railways are among the largest of that class of industrial concerns which produce more than one commodity or render more than one service, and which, therefore, have a « joint cost ». Every well conducted concern having a « joint cost » tries to develop a good system of cost accounting so that it may know as nearly as possible what each commodity it makes, or each service it renders, costs; but, while the costs arrived at often are close approximations to the truth, I doubt if the accountants of any concern having a « joint cost » would say that they arrived at the exact cost of producing any commodity or rendering any service, unless the operations are very simple indeed. Furthermore, if the commodities produced or the services rendered differ widely in their values to those who buy them, no concern would succeed if it tried to make the price or the rate charged for each commodity or service the same as the total costs incurred in producing the commodity or rendering the service. The chief value of a detailed and thorough cost system to a concern having a large « joint cost » is to serve as a guide to its management in effecting economies and in discontinuing operations which are shown to be resulting in the production of commodities or services which cannot be sold for as much as the production

or rendering of them *adds* to the total expenses.

Regarding the relationship between railway cost accounting and rate-making, the Interstate Commerce Commission has said, (30 I.C.C. 679) « The assumption that railway cost accounting cannot be made sufficiently accurate for useful consideration in dealing with rates does not seem warranted. Although not possible twenty years ago, it would appear that at the present time approximately two-thirds of the operating expenses of a railroad can be separated in a reasonably satisfactory manner. The separation of the remaining one--third is useful if a basis is selected which equitably measures the use which either service makes of many facilities ».

It will be noted the Commission does not say that railway cost accounting can be made sufficiently accurate to make it practicable to base rates on costs, but merely implies that the results obtained can « be made sufficiently accurate for useful consideration in dealing with rates ». The writer does not dissent from this general conclusion. His conclusions are as follows :

(1) The method adopted by the Interstate Commerce Commission for separating operating expenses between passenger and freight train service will make it practicable to draw correct general conclusions as to the relative operating costs of freight and passenger train service in the United States.

(2) No method for allocating property values or capital charges between freight and passenger service has yet been devised which is at all satisfactory. All the allocations of this kind thus far made have been based on hypotheses which are open to destructive objections.

(3) Enough of the total operating expenses may be accurately divided between the freight and passenger services, and enough more of them may, with good reason, be assigned to the respective services to make the information obtained useful in determining the relations that should be maintained between freight and passenger rates. Furthermore, enough information may be obtained regarding a large part of the costs of handling mail, express and passengers on passenger trains, and of handling different kinds of freight under similar and differing conditions, to throw light on the way in which the rates for different services should be adjusted. On the other hand, no system of cost accounting can ever be devised which will disclose with even approximate accuracy the total cost, including capital charges, of the innumerable individual services rendered by railways in the transportation of freight and passengers; and, furthermore, if these costs were accurately ascertained they could be used only as one among many guides in fixing rates, since it is fundamental that, if the welfare of both the railways and the country are to be furthered by the development of a large traffic, rates always must be based primarily on « what the traffic will bear », having due regard for competitive, economic, industrial and transportation conditions.

[625 .17]

REPORT No. 4

(all countries, except Great Britain and America)

ON THE QUESTION OF THE MAINTENANCE AND SUPERVISION OF THE TRACK (SUBJECT II FOR DISCUSSION AT THE NINTH CONGRESS OF THE INTERNATIONAL RAILWAY ASSOCIATION), (1)

By Joseph BARBIERI,

ENGINEER,

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INTRODUCTION

We think it advisable in the first place to set forth in a few words the scope of our report, and to indicate in a general manner the fundamental ideas that we have followed in its compilation. The subject we have been requested to deal with is one of great importance, especially at the present time, when the organisation of the Railway Administrations are suffering from the effects of the disturbed conditions which the recent political and social events have caused throughout the whole world. It is extremely complex as it deals with many and widely different forms of work of each Administration. Unfortunately the time at our disposal has been very limited, consequently we had to make our detailed questionnaire as simple as possible, and only to include the more important points and those which have a greater and more direct influence on economical working. On the other hand, the Administrations which have been good enough to reply have certainly not been able to deal with all the questions as fully as one might desire.

We sent out the detailed questionnaire to twenty-four Administrations (those in Germany not being included), and seventeen of these replied.

The lack of detailed replies is the reason that certain questions have only been dealt with in a general manner in our report, and some, which we deem to be of secondary importance, have not been considered at all.

Moreover, the cost of material and wages has, during the course of late years, increased to a very large extent, varying with the conditions existing in the countries under consideration. It has therefore been very difficult to differentiate between the effects of temporary condi-

(1) This question runs as follows : « Measures to be taken to provide an economic organization for the maintenance and the supervision of the track, taking into consideration the increase of traffic and speed as well as the rise in wages and in cost of materials. Use of mechanical appliances. Results obtained ».

tions and those which result from permanent causes, and it has been impossible to make comparisons in our report between the cost of maintenance on the different Administrations, to compare present day costs with those ruling at the time of the last Congress, or to give actual figures in support of our conclusions. Since however the abnormal conditions, which at the present time affect the cost of materials and wages, will certainly tend to disappear in a few years time, it would, in our opinion, be desirable that this question should be dealt with in a more definite report at a future Congress.

Organisation of the maintenance department as regards the administrative staff.

As a general rule, the Maintenance Department is organised as a department independent of the others concerned in working the line, that is to say, from the Traffic and Motive Power Departments.

Ten Administrations have their systems divided into divisions, each division into sections, and each section into subsections or districts.

Four Administrations do not have sections and districts. One of these, the French Midi Company, divides its system into divisions, and such divisions into sub-divisions, which are, we believe, comparable to districts.

The average length of a division varies from 500 to 1 300 km. (310 to 800 miles); that of sub-sections being from 60 to 300 km. (37 to 185 miles); that of subsections and districts being from 10 to 90 km. (6 1/4 to 56 miles).

The increase in salaries has caused practically none of the Administrations to make any modification in the organisation of the staff controlling the Maintenance Department. Two Administrations, however, have increased the length of some of their districts. The Italian State Railway is about to abolish some of its sections and to put the districts directly under the control of the divisions; and the Administration of the Swiss Federal Railways has considered the extension of its sections and districts. As regards the results obtained or anticipated, no particulars have been given.

We do not consider it advisable to deal in detail with this side of the question, being of the opinion that the organisation of the supervisory staff will largely depend on the particular geographical and social conditions of each country.

Personally, we believe that the best organisation from a technical point of view is that in which the system is divided into sections of a length equal to or even greater than 185 miles directly responsible to the chief of the department, and the sections divided into districts. It is advisable that the Maintenance Department should be quite separate from the other departments connected with the working of the line, in cases where the railway is of any considerable length. Furthermore, we do not consider that it is advantageous to have officials exclusively responsible for the maintenance of the track, and other officials responsible for other engineering work on the railway, etc.; except in cases where works of exceptional importance are entailed, or where special experience is required. However, we are of the opinion that it is convenient, at the present time, to have, in each section, an official specially detailed to control the engagement of temporary labour, the use of new material, the sorting of material taken out of service, and the

economic use of that which is not absolute scrap.

Organisation of the maintenance department as regards working staff.

All the Administrations, as regards maintenance, have divided their districts into « lengths » entrusted to gangs of platelayers, varying in number according to the conditions of the line.

Some Administrations, for example the Italian State Railways, also include in their maintenance department the men responsible for looking after the level crossings and the watchmen employed in guarding the line. The extent of the « lengths », stated in terms of single line, ranges from 2 1/2 to 7 1/2 miles for eleven Administrations. The number of men forming a gang varies on seven Administrations from two to ten in addition to the ganger. An inspector has the control of a group of gangs (up to five).

The other Administrations have only given brief replies on this point; however, it appears that some of them, in the composition of their gangs and the extent of their « lengths », exceed the numbers and « lengths » stated above. For example, the Swiss Federal Railways have « lengths » ranging from 11 up to 19 miles.

It may be gathered from the foregoing that in general the Administrations have preferred the system of small gangs for current maintenance, while for important works, to group several gangs together, or to have recourse to temporary labourers who are engaged when and as required, and who are discharged when the work is finished. This system is the most economical for the short « lengths » of present day practice, since it enables a small number of permanent employees to be kept on throughout the year, thus ensuring maintenance being performed in a satisfactory manner.

Only two Administrations have given complete replies on the question of steps to be taken to reduce the expense of the maintenance staff in view of the rise in wages. The remainder state that the subject is still under consideration, or merely mention that new arrangements have just been put in hand.

The French Northern Company has found considerable economy by applying to its line the « general relaying » system.

The Paris-Orleans Railway has adopted as an experiment, on a line carrying light traffic, a new organisation with «lengths» 18 1/2 miles and gangs of ten men, relying on « draisines » for transporting the men and materials.

Some Administrations employ contractors, but only for special work (cleaning the ballast, or complete relaying of the track), similarly the French Eastern Railway entrust to private enterprise certain operations of the general over-haul (renewal of ballast and re-ballasting the track) while the Italian State, the Belgian State and Portuguese State Railways have also tried the same system.

The Italian State Railways have made their experiment on a large scale, choosing « lengths » of various conditions of lay-out and traffic.

They have employed either small contractors or co-operative societies of workmen, who work with ordinary tools, allotting to them a « length » of 6 1/4 miles or a contractor who deals with long « lengths » by means of Collet's patent machines, entrusting him with about 53 miles of track. The results have not been altogether favourable up to the pra-

sent, or else the result is as yet uncertain. None of the Administrations have considered the possibility of entrusting the work of relaying to the ordinary gangs on piece work, or rather of allowing a certain time for each operation, nor have they given any particulars of experiments made in this direction. One Administration states that so far as it is concerned it is entirely opposed to the system of carrying out relaying on a piece work system.

The Italian State Railway, before the war, had introduced upon part of their system a species of piece work, either for the men of the regular gangs, or for the temporary labourers.

The minimum daily task per man was fixed for each « length » and a bonus paid for each metre of track relayed over and above this amount. The system has not yet been resumed, although the past results were satisfactory.

We are of the opinion that it may be advantageous to increase the extent of the « lengths » on lines carrying light traffic, since on these the upkeep will not be continuous between the period of one relaying and another. This solution of the problem enables the strength of the gangs to be reduced by grouping them together and dispenses with one or more gangers. It will however be necessary with such a system to provide rapid and economical means of transport for both men and materials.

The system of employing contractors for the work of general relaying appears to be in little favour with the Administrations. We believe that this is, to say the least, exaggerated.

Assuming that the supervision is sufficiently strict, we are convinced that it is possible to obtain results as good as those produced by work directly carried out by the Administration, and even in some cases more economically.

The present day output of workmen in general, and particularly of the employees on the regular staff of the State Administrations, does not correspond with the great increase in wages. Only the direct and interested supervision of a contractor can overcome this unfavourable tendency, and obtain greater activity and more efficient methods.

On the other hand, workmen who seek employement with the contractors more readily accept lower wages than those employed by the great State or private Administrations, and accept piece work instead of day work. For this reason we believe that it may be advisable to follow this question more closely.

Methods of carrying out maintenance work.

We are in complete agreement with almost all the Administrations that have replied, in recommending the method of general relaying of the track, that is to say the system of completely relaying each year a part of the line of a length depending on the particular conditions of its construction and traffic carried. When this entails the necessity of changing the type of rail, we believe that it will be advisable to renew all details of the track. The result will be a track in perfect condition, allowing the periods between general relaying to be increased, and meantime cutting down the minor maintenance repairs.

As regards ballast, many Administrations have tried the system known as « soufflage », which consists of screening the ballast from between the sleepers down to their lower surfaces, without

disturbing that which is below this level. The light material separated by screening is used for lifting the track, and the screened ballast replaced.

It appears to be almost certain that this system gives satisfactory results, and we are of the opinion that it is good practice to apply it whenever the ballast is sufficiently good or where the sub-soil is firm.

The Northern Railway Company appears to carry out the cleaning of the ballast between the sleepers at the same time as the general relaying.

We believe that this practice has much to recommend it, as the durability of the wooden sleepers is better assured thereby. In our opinion, however, it is not advisable to carry out the cleaning of the ballast at the same time as the general relaying in order to avoid undue delay to traffic. The simultaneous carrying out of these two classes of work is justifiable if the line can be closed for the necessary time.

Types of rails used and their effect on maintenance.

Generally speaking, the Administrations have adopted two types of rail, a heavier one for the main line, and a lighter one for branches. A third and still heavier type has been adopted by some Administrations for use in tunnels.

Three Administrations use double headed rails with chairs, while the others use « Vignoles » rails.

The French Midi Railway has adopted metallic keys for its double headed rails. Nearly all the Administrations place their « Vignoles » rails on metal sole plates; The French Eastern Railway is the only one using sole plates of compressed poplar wood.

The weight of the rails on the main lines is usually from 76 1/2 to 101 lb. per yard and from 101 to 110 1/2 lb. per yard in long tunnels. On branch lines it is from 38 to 76 1/2 lb. per yard.

The length of the rails on the main lines varies on most of the Administrations from 36 to 72 feet. On the branch lines it varies greatly, the length being from 18 to 72 feet.

The number of sleepers per yard of track is from 1.01 to 1.37. Nearly all the Administrations use sleepers of oak, pine or beech, usually creosoted.

The French Midi Railway also uses sleepers of pine impregnated with sulphate of copper.

Three Administrations have metal sleepers on their lines, and one also uses sleepers of reinforced concrete. The results of these experiments with the metal sleepers appear to be satisfactory, and the French State Railway hope to effect economies by extending the use of the « Vignoles » rail carried on metal sleepers on their branch lines. It is fully appreciated by all the Administrations that the first essential towards reducing the expenses of maintenance is to have a track properly designed to suit the volume of the traffic and the speed of the trains, and for this reason it is advisable to replace as soon as possible rails that are too light by those of a heavier section, and to increase the number of sleepers in cases where the pitching of these is wider than 1.2 per lineal metre (2 feet 8 3/4 inches from centre to centre).

The weakest point in the track remains the rail joint, and naturally the Administrations have given much attention to the question of improving this, either by special forms of fish plates or by other means.

We consider that it is of interest in this connection to remember some experiments which have been made to this end, but by quite another method. The Italian State Railways have tried, as an experiment, *viz.*, the placing of a kind of grating of reinforced concrete below the two sleepers next to the joint. This is a German patent and is intended to give a firmer support to these two sleepers.

The Swiss Federal Railways have, for the last ten years, replaced the suspended joints by joints supported on double metal sleepers, or on two wooden sleepers.

The Danish Railways have used sleepers bolted together under the joint. In the light of experience gained on the 3 ft. 1 3/8 in. gauge lines of the Italian State Railways, this latter system does not appear to be advantageous, since it renders it difficult to pack the ballast under the joint sleepers, the very place where this packing is most required.

The Swedish State Railways have tried rails having the head shaped in the form of a letter S. No report is given as to the results, nor have we been given sufficient information to be able to form any opinion on the device.

Finally, some Administrations claim to have effected an economy in sleepers by using metal or hard wood liners on soft wood sleepers, and also on second-hand hard wood sleepers. On the other hand, some Administrations report unfavourably on these methods.

Supply and distribution of material. Use of material. — Second-hand material.

We are of the opinion that is is advantageous to supply the permanent way material for the whole system, with the exception of ballast, through the headquarters of the Maintenance Department, distributing it of course to one or more stores, according to the importance and extent of the railway system. This method may cause some extra transportation, but allows a better control to be exercised over the quality of the materials, which are inspected according to standard specifications and bought at the most advantageous price. It is, however, necessary with this system that the maintenance staff should always have in hand a certain amount of material, and we are of the opinion that at any rate for special permanent way material it is advisable to establish a store in each division or section.

As regards the ballast however, we consider that it is more economical, in view of the cost of transport, to leave the provision of this to the divisions or sections in the neighbourhood of the lines on which the work is to be carried out and as and when it is required.

As regards the use of permanent way material, the care of tools and economy with various stores, this has up to the present only been controlled by keeping accounts. In our opinion it is necessary to-day to establish a more efficient direct control, and to consider means to interest the staff who carry out the work in such a way as to economise material and stores, and to take greater care of the tools with which they are entrusted.

Only one Administration, the Portuguese State Railways, has informed us that it has tried experiments in this direction, and during the war obtained good results. We regret that we have not received sufficient details to enable us to go thoroughly into this very important question. It is certainly a difficult and complex problem, but we consider that pre-

sent day conditions demand that it should be carefully studied.

As regards material recovered from the track, either in the course of maintenance or during a complete or partial relaying, or from minor alterations, we would draw the attention of the Administrations to the fact that herein may lie another source of appreciable economy.

As a rule, the Administrations content themselves at the present time with having a statement made of the condition of the material withdrawn, having the same inspected to separate that which is fit to be used again from that which is scrap, and with giving instructions as to the efficient re-use of the former and the disposal of the latter.

There is always a certain amount of the material which, in the ordinary course of events, would be considered unfit for further use and which one might attempt to repair or to use for other purposes to greater advantage than merely selling as scrap.

The Italian State Railway has lately tried direct control over materials which have been condemned to be sold as scrap. In this way they avoid selling any material which is in serviceable condition,such as fish plate bolts without nuts, nuts themselves, etc.; further they have been able, with a certain amount of success financially, to repair and render fit for reuse, spikes, bolts with damaged threads, cracked fish plates by welding by the oxy-acetylene process, and screws by converting them into spikes.

The Italian State Railway has also tried selling short lengths of rail which cannot be used, and this method has up to the present proved advantageous. They send these short ends to steel works in exchange for a proportional weight of rolled joists or round bars for reinforced concrete. The ratio is from 3.5 to 4.0 kgr. of rails to 1 kgr. of rolled joists or round bars.

We suggest that this method deserves consideration, and are of the opinion, as we have said above, that it would be very advantageous to allot, at least to the divisions and sections, an inspector whose special duty would be the control of the use of material, the care of tools and the careful sorting and classification of material taken up from the track.

The employment of mechanical appliances for maintenance work, the use of special wagons and lorries for transporting material, maintenance gangs and officials.

Generally speaking, this question has yet to be thoroughly taken up; it is in course of progress, but only to a very limited extent.

Some Administrations use machines to bore the holes in the wooden sleepers, for example, the Danish State Railways have this work done by contractors who bore one end of the sleepers only by machines at their workshops. The Swedish State Railways use machines for tightening bolts and screws.

None of the Administrations gives details of the results obtained.

On many Administrations, machines for boring sleepers, for tightening up or unscrewing bolts and screws, and for ramming ballast, are only applicable where the work is on a large scale, and are not on the whole economical for relaying work. The Portuguese Railways state that their results in this direction have been anything but economical.

Experiments have also been made with

the use of special wagons to carry ballast and to discharge it rapidly along the line and also with machinery for loading wagons at the ballast pits.

Two or three Administrations are experimenting with a method of keeping down weeds by means of a machine mounted on a wagon, and although it may be necessary to further improve this device, it appears that economical results may be obtained by its use.

Finally, a number of Administrations use, to a fairly large extent, « draisines » and pedal quadricycles to convey workmen and officials, and « draisines » or motor trucks to transport both material and tools. The use of these has given in general very satisfactory results.

The French Northern Railway is gradually replacing the lorries for transporting material by « diplorys », that is, by special trucks which can be taken to pieces and which are mounted on ball bearings.

Our opinion as to the employement of machines on maintenance work is, that it would be of real advantage if the organisation of the work were carefully thought out, if the men who operate the machines had the necessary experience, and in particular if used where there is work of a considerable magnitude such as a general relaying of the track.

The results obtained from their employment are doubtful when in the hands of the ordinary gangs occupied on general relaying, but we are of the opinion that even in such cases, at least ballast ramming machines may prove advantageous both from a technical and economical point of view. If good results have not up to the present been obtained with ballast rammers, this may be on account of the type of machine, or of dealing with the work on unsuitable lines, based on those formerly used with hand tools.

The compressed air rammers, which up to the present can only be used by ordinary gangs, have the disadvantage of the noise caused by the exhaust of the air. This makes it necessary to carrefully protect the scene of operations by danger signals, and to keep a sharp look out.

According to our personal experience, sleepers can be packed better by machine than by hand, and the ballast less broken up.

According to articles which have appeared in the American technical press, the output is double of that obtained with hand tools.

We believe, therefore, that we are correct in insisting that all the above mentioned mechanical devices should be tried for maintenance work, since in all fields of human activity the machine has eventually proved its superiority. Economic results are of still greater importance today, when workmen's wages have risen considerably, and their output is on the other hand very much less.

Organisation of the staff employed in the inspection of the line.

In the following, for the sake of simplicity, we shall include under the above title those employed to look after level crossings, to attend to the lighting of signals at night, and to repeat the fixed signals by means of detonators during fog, snow or bad weather.

The supervision of the permanent way is carried out by periodical inspections by inspectors and gangers, and by inspections daily or even several times during

the day by platelayers detailed for the duty. On some Administrations these men are members of the maintenance gangs and make their inspection first thing in the morning before joining their gang, and in the evening when returning from work. The amount of track that they have to inspect depends on the extent of the « length ».

On some Administrations this duty is performed by the level crossing keepers during the interval between two trains or before the first train in the morning. In this case the length of line to be inspected is somewhat less than in the preceding case, being 5/8 to 1 1/4 miles.

Finally, some Administrations have special employees « road-guards » (« gardes-routes») who are responsible for these inspections and who are used for other purposes (duties at level crossings, lighting up and care of signals, minor maintenance repairs, etc.) only when the length of line and the number of inspections to be made allows them sufficient time. In this case, the length of track to be inspected is much greater and is as much as 13 kilometres and sometimes 16 kilometres (8 or 10 miles). These « road-guards » are allowed to return home by train, after having completed their inspection.

Of these three systems, we prefer the last. The second, as we shall explain later, is not always practicable, or advisable, in view of the steps which ought to be taken, on account of the rise in wages, to reduce the number of level crossing keepers.

The first system seems to us to be uncertain in its results, since one part of the « length » may be inspected with more or less trouble, according to where the gang is working. It is perhaps economical if the « lengths » are limited to the usual present day amount, but the economy will disappear if the « lengths » are increased, as certain Administrations have tried to do, and as we believe may be done with advantage so as to reduce the number of the maintenance staff.

The « road-guard » system on the other hand gives a sufficient guarantee that the inspection is properly carried out, and allows a better control to be exercised over the staff and effects a substantial economy, if at the same time the level crossing keepers are abolished.

An economy in personnel can easily be realised by reducing the frequency of inspection. The necessity for these tends to diminish, in view of the improvements which have been made in the manufacture of permanent way material, in the type and construction of the track, and with the care which is taken nowadays in maintaining the line.

Except in the case of lines where contions are exceptional, we believe that one inspection per day is enough, even for lines with important traffic.

On the branch lines, where the traffic is light, we are of the opinion that it is unnecessary to inspect the line every day. We are referring here to lines where the conditions are normal and on which there is no possibility of land slips, falling rocks, etc., and it should also be noted that the inspections carried out by the railway staff are not with the object of discovering or preventing malicious acts.

A very important question as regards economy of personnel is that of the abolition of level crossing keepers. Obviously the ideal solution would be the abolition of level crossings themselves, carrying the road either over or under the railway. This, however, in most cases, entails very considerable expense and is moreo-

ver almost impossible in some places. It is much easier, according to the local conditions and to the law of the country, to use gates controlled from a distance where the crossing keeper has to be retained; to make the owner, where the road is not a public thoroughfare, responsible for the crossing; to substitue women gate keepers; to entrust the supervision of level crossings to private enterprise, or to leave level crossings, under certain circumstances, without a crossing keeper and without gates, and allow the public to pass at their own risk.

The Administrations which have replied have in a number of cases adopted these arrangements, particularly the Italian State Railways.

The level crossings which are left open and ungarded are provided with warning posts which are very prominent and quite different from ordinary posts which one encounters by the roadside. As a rule they are not illuminated at night time, it being considered that they are sufficiently visible, being painted black and white. However, for the more important crossings provision is made for lighting these posts either by electric light or with acetylene flash lights, and finally for use of signals of the American type which automatically give warning of the approach of trains.

The economy which may be derived from such arrangements is certain, but one must wait for the results of several years experience to judge as to the consequences to the public, and also as to the possibility of perpetuating these open level crossings.

One can also effect an economy in staff by having the signal lamps lighted day and night, or better still, by lighting them electrically or by acetylene flash lamps, which we have mentioned above, this perhaps also effecting an economy in stores.

Some Administrations have already experimented on the above lines, and the results obtained appear to be altogether satisfactory.

The repetition of signals by detonators is in use on a large number of the Administrations that have replied, and on one of them, these are still placed in position by hand.

The French State Railway has given up the use of detonators in favour of equivalent devices which are not described in their reply.

The Belgian State Railway, on lines worked on the absolute block system, give warning that a distant signal is being approached by means of five white sign posts spaced 55 yards apart, and numbered with black figures.

The Italian State Railways have also tried a similar device, but with unsatisfactory results. They intend to repeat the experiment, with certain alterations to the sign posts and their location, to give a clearer view to the footplate staff.

We believe that we should draw attention to the question of repeating signals by means of detonators, and recommend that they should be placed on the rail by mechanical means, or better still, automatically by the movement of the signal. We are unable on the other hand to definitely recommend the system adopted by the Belgian State Railways, since they have not given sufficient information of the results obtained.

Duties at signal boxes on the main line.

On some Administrations the maintenance staff are sometimes required to work the main line signals and to take duty at the signal boxes. Where the block system is in use, a considerable

economy in staff can be effected by the adoption of automatic systems. The economy would be very appreciable, as it is a matter of dispensing with at least three men for each signal box, not however overlooking the fact that the automatic systems will require an increase in the staff who repair the signals. We are convinced that the automatic block should be brought into general use, and we prefer the system in which the signals are normally in the danger position.

The Administrations which have sent in replies have nearly all gone into this problem, and one of them, the French Midi Railway, has already adopted the automatic block system for lines carrying the heavier traffic.

CONCLUSIONS

As regards the organisation of the supervisory staff, it is difficult to advise as to the most suitable system, since it depends mainly on the particular conditions of the railway and the country. We are of the opinion, however, that it is necessary at the present time to appoint inspectors to deal solely with the control of supplementary labour and material, and also with the efficient use of material withdrawn from service.

As regards the organisation of the maintenance working staff, we are of the opinion that it is advisable to enlarge the « lengths», group together the gangs, provide rapid means of transport, and introduce the use of machines.

We favour the application of a system of fixing a time for each job in ordinary maintenance work directly carried out by the Administrations, and we recommend that further experiments should be made with entrusting this work to contractors.

As regards special work, we are of the opinion that it is better to employ contractors.

We recommend the « general relaying » system for the track and that known as « soufflage » for the ballast.

A strong well laid track is the best for economic maintenance.

We consider that it is as a rule advantageous to supply permanent way material from a central store, and to establish smaller stores in the divisions or sections.

The Administrations ought to turn their attention to the possibility of making it to the interest of the staff to economise material and to take care of their tools, and also to re-utilise material withdrawn from service, and upon the possibility of repairing and making fit for use that which has been condemned as unfit for service.

We strongly advise the introduction of machines for maintenance work.

As regards the organisation of the inspection of the track, we are of the opinion that the system of « road-guards » is advantageous, thus the frequency of the inspections may be still further reduced.

The abolition of level crossing keepers, the application of flash lights or electric lights for signals, the use of mechanical devices for placing fog signals, and finally the introduction of the automatic block system, are measures that will effect great economies.

[656 .212 & 725 .32]

REPORT No. 1

(all countries, except Italy and those using the English language)

ON THE QUESTION OF GOODS (FREIGHT) STATIONS (SUBJECT X FOR DISCUSSION AT THE NINTH CONGRESS OF THE INTERNATIONAL RAILWAY ASSOCIATION), (1)

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and

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Figs. 1 to 12, p. 159 to 188.

N. B. — All the replies from the Railway administrations that have served as the basis of this report were received in 1914. It follows that the whole of the particulars and of the conclusions that have been drawn from them relate to pre-war conditions, conditions that have since become extremely different in almost all of the countries that replied and particularly so in the case of those engaged in the war.

It would, moreover, be extremely difficult to place any reliance on existing conditions which may only be transitory, either because the new tendencies resulting from these events may develop, or on the other hand because economical considerations may cause retrenchment. This has not, however, prevented us from alluding to some of the difficulties of the present and to the solutions which have enabled us to face them.

* * *

The chief subject of question X is the organization of goods yards for the dispatch and delivery of goods and the improvement in their communications. It is almost unnecessary to draw attention to the importance of this question and to the influence on the commerce and industry of a country that is exercised by the working of its goods yards. This influence has been only too well brought to light by the general transport deadlock that has resulted from the war, the tremendous effects of which have only begun to diminish after about two years of

(1) This question runs as follows : « Organization of the receiving and the delivering stations, so as to accelerate their business. — Arrangement of the buildings and tracks so as to simplify shunting (switching) operations and handling, particularly as regards goods in bulk. Mechanical appliances. »

peace. At the present time when railway traffic tends continuously to increase it is more than ever necessary to obtain the highest efficiency from the rolling stock as well as from the plant and track. These two components of the traffic are intimately related to each other; it is only by the careful design of the arrangement of goods yards, whether inland or seaboard, that it is possible to reduce the standing time of the wagons when loading and unloading.

The effect produced in this respect by a good arrangement of the yard is further influenced and assisted by a judicious selection of the commercial conditions for the traffic. It is most important that these should be such that the unloading and loading of the wagons available for the public should, as nearly as possible, be effected simultaneously.

Also the regulation of private sidings has a great influence on the release of the rolling-stock that is left standing on them for loading or unloading.

We have therefore thought is necessary to introduce into the list of questions, that we have sent out to the Administrations concerned, some sections relating to the commercial conditions of transport and to private sidings, although these subjects might, at first sight, appear foreign to the question before us.

Our report will be divided under the following heads :

I. — The influence of commercial conditions. — Private sidings.

II. — Ordinary goods yards.
- *A.* — Arrangement of tracks.
- *B.* — Arrangement of warehouses.
- *C.* — Auxiliary appliances.

III. — Seaboard goods yards.
- *A.* — By-laws, administration and commercial.
- *B.* — Arrangement of buildings and tracks.
- *C.* — Auxiliary appliances.

IV. — Conclusions.

CHAPTER I

The influence of commercial conditions. Private sidings.

The necessity for arranging that unloading and loading should take place as nearly as possible simultaneously. — In order to expedite the service of goods forwarding and delivering yards, the ideal arrangement would be to be enabled by two shunting operations only : *a*) to put the empty wagons required for despatch and the full wagons requiring to be unloaded by the consignees at the disposal of the public and *b*) to remove the wagons that had been loaded as well as those left empty after unloading by the consignees. In other words it would be necessary, as stated in question 1° of the list of questions, that the loading and unloading of the wagons put at the disposal of the public should be performed simultaneously and in the same period of time for the whole of the wagons.

At first sight this does not appear impossible; but it will readily be seen that if a few of the wagons only that make up the train are delayed either in loading or in unloading it will be impossible to carry out the operation by hauling out the train but that lengthy shunting operations will be necessary. A few wagons that have not been unloaded by the evening may paralyse the operations of an unloading bay for the next morning. The Railway

Companies are obliged to reckon with these delays which are sometimes the fault of the public and sometimes a case of *force majeure*. But, as any delay seriously affects the working of the traffic, and is inimical to the interest of commerce and of the Companies, the latter make every effort, by suitably framed by-laws, to urge the public to effect the operations of loading and unloading in the shortest time possible.

Clauses and conditions for the carriage of goods. — The various clauses framed for this object are : the laying down of time-limits for loading and unloading, special rates, penalties for delay, bonuses for clearing early, and finally the right of the Companies to unload and cart away goods themselves when the yards are congested.

The best means of avoiding the numerous shunting operations, that disturb the handling of the goods and increase the time taken, is to do the shunting before the commencement and at the end of the working day at those times when the yards are not open to the public. For this reason the greater number of the European Companies have fixed the time limit for loading or unloading a wagon at 8 to 10 hours, that is to say approximately the length of the working day. This limit is 12 working hours in Norway and 24 hours in Denmark. It is also usually 24 hours in countries oversea, particularly in Algeria and Tunisia.

In case of congestion or of risk of congestion the time allowance is frequently reduced. Thus on the tracks of the port of Antwerp it is 4 hours (instead of 8 hours which is the allowance on the remainder of the Belgian State Railway system). Similarly on the Danish State Railways the normal allowance of 24 hours may be reduced, after notice has been given, to 9 hours or 6 hours in the day-time. The same regulations apply on the Bona-Guelma Company in Tunisia.

A rather large number of Companies have introduced specially low rates for bulky and heavy goods (coal and minerals) on the condition that there is a corresponding reduction in the time limit. These rates which form a variant of the bonus for quick clearing have been applied on all the French railway systems, almost entirely on the French Northern Railway and to some extent on the French Eastern, Midi, Orléans and Paris-Lyons-Mediterranean as well as by the Bona-Guelma Company. On the French Northern Railway system the rate is conditional on (1) a time limit of 6 hours in one shift and it includes coal, iron, sand, beetroot, etc. To enable it to be put into force the yards are required to get into place, before 11 or 12 o'clock, wagons containing goods of these classes that arrive during the morning.

Almost all the Administrations impose penalties for delay in loading or unloading the wagons. These penalties are not generally proportional to the delay, but increase progressively, that is to say the rate is considerably increased when the delay exceeds two or three days. The scale of penalties varies greatly; in some instances they are charged on the truck (demurrage) and in some on the tonnage. The time unit on which they are based is in some cases the day and in others the hour.

On the French and Algerian Railways the penalty (demurrage) per wagon is :

15 fr. for the first day;
20 fr. for the second day;

(1) See the first two paragraphs of the introduction to this report.

30 fr. for the third and following days, exclusive since the war, of temporary increases and of tax.

The bonus for saving time is not very general. Among the replies that have reached us it is only mentioned in those of three French Administrations : the French Orleans, State and Northern Railways. On the Orleans and the State Railways a whole day must be saved for a wagon. On the French Northern Railway it is sufficient that the wagon which should be cleared on the siding at the expiration of six hours, should actually be cleared in the evening and given over at the earliest moment although it may not have been available for more than one or two hours before the legal closing hour of the yard.

The right reserved by nearly all the Companies in their by-laws, but seldom enforced, is that of themselves unloading the wagons at the expense of the consignee. The French railway systems in this case make a charge of 0.30 fr. per ton over and above the ordinary warehousing rates quoted in the tariff. When the Company does the unloading by right this generally involves carting as well by the Company at consignee's expense to his place of business or to a public warehouse. In France this right can be exercised if the consignee has not removed his goods within 48 hours of the expiry of the normal time limit.

Rules relating to shunting hours. — The regulations that we have mentioned are intended, as we have mentioned, to encourage the public to load or unload the wagons in the shortest possible time so as to enable the Companies as far as possible to effect the shunting operations of removal and of putting wagons in place by complete trains and at fixed times. Actually this end is never completely attained and the shunting operations are carried out according to a definite scheme and in such manner as to cause the minimum of inconvenience to the despatchers and consignees.

In large yards the best rule to follow is that of only putting the wagons in place at the unloading wharves during the night and only hauling away the loaded wagons in the evening after the loading operations of the despatchers have been completed. This rule, it is true, leaves some of the wagons standing idle and consequently occasionally involves an extra shunting operation which may be performed about noon during the dinner hour of the railway and private labour.

In small yards, having no special shunting engines, these operations which are never very lengthy are effected by means of the locomotives of passing trains (and consequently at regular hours which are known to the public) ; in some cases they are even performed by man-power with the assistance of pairs of turntables for transfer from one road to another.

Warehousing. — By « warehousing » is understood the facility afforded to the public sending goods by rail to leave these in the warehouse on the Railway Company's property for a certain period of time, either before despatch or after arrival, on the payment of certain dues.

This facility enables the wagons to be cleared more rapidly; but the public may be temped to abuse it and this results in an inextricable blocking of the open and closed sheds, yards and warehouses. For this reason in nearly all countries the rates have been so arranged as to discourage storage for any length of time and may even be such as to become prohibitive when the period exceeds a certain

limit only exceeded in obvious abuse of the facility. The rates are consequently not proportional to the time but increase progressively.

The rate for warehouse room, on the French railway systems is as follows (1):

Per 100 kgr. (cwt.) or fraction thereof :
0.20 fr. for the first period of 24 hours;
0.40 fr. for the second period of 24 hours;
1.00 fr. for each period of 24 hours additionnal to the above.

For demurrage of wagons there is a special rate (1) of :

5 fr. for the first period of 24 hours;
10 fr. for the second period of 24 hours;
15 fr. for each period of 24 hours over and above this

In Norway the rate is charged, in large yards, per square metre of area occupied. In small yards no charge is made except in cases of definite abuse of the facility.

In Sweden, the rates are proportional to the time and sometimes to the area occupied, sometimes to the weight of the goods.

In Switzerland the rates are proportional to the weight and are increased progressively for time. The rates increase after the first three days.

In many countries there are special lower rates for goods left on the ground for long periods and other rates above the normal for goods kept standing on the wagon.

Lastly a fairly large number of Administrations afford facilities to merchants for storing goods on plots of open ground at so much per square metre per month or per annum.

(1) See the first two paragraphs of the introduction to this report.

Private sidings. — The question as to whether the installation of private sidings is capable of reducing the work done in the yard, of freeing the lines used for trade and hastening the departure of the wagons, is open to controversy, and the most diverse replies have been received on this subject. Many of the Companies are in favour of their installation and make efforts to encourage their adoption by a broad and tolerant set of by-laws. Other Companies on the contrary are of the opinion that the advantages they present are out of proportion to the expense they occasion and the demands they make on the service for running the wagons on to the sidings.

In Belgium, in Switzerland and in France the general consensus of opinion is in their favour; nevertheless the French Midi Railway raises an objection to sidings with small traffic, the service for which rather tends to increase the work at the stations and does not allow the wagons to be cleared rapidly. The Orleans Railway Company states that if the private siding does definitely reduce the operations in the goods yard on the other hand it is sometimes responsible for complicating the shunting operations required for making up the train.

As to the rapidity of clearing the wagons there is an advantage whenever the local conditions allow the private siding a sufficiently frequent service.

Private sidings are rare in Algeria where agriculture is more important than manufacture; they are more common in Tunisia, where in response to the requests of the mining Companies, the Bona-Guelma Company has installed a certain number and has expressed itself as being satisfied with the results.

Laws. — Administrative and technical

regulations. — Road crossings. — Though private sidings are not always economical from the point of view of the Company they are nearly always for the public; it is evident that the manufacturer or merchant at the head of a large business finds it to be of the greatest importance to have inside his works or alongside his stores a line of rails by which he can receive his raw materials or load his goods on to wagons. The laws of all countries possessing railways, even though these are only of small extent, facilitate the construction of these sidings; the installing of the sidings is nevertheless subject to certain technical and administrative conditions.

On the technical side, the conditions imposed are such as to meet the necessity for safe working and to reduce to the minimum the difficulties introduced into the running and working of the train service. From the administrative point of view the installing of a private siding generally involves the passing of an agreement which in most countries is subject to the approval of the superior authority (generally the Minister of Public works or his equivalent).

In France, the law only requires that private sidings are to be installed for mines and factories. But actually the Companies themselves encourage their adoption for all classes of commerce and industry.

The wording of the French law says nothing with regard to sidings connected with the main line by turntables. Their use is therefore left to the discretion of the concessionary Railway Company. In most cases the use of the turntable is the affair of the manufacturer.

Sidings taken from main lines may always be refused on the grounds of the higher importance of safety. In fact the permission to obtain these sidings is being withheld more frequently on account of the increase of traffic on the main lines.

The arrangements relating to the crossing or following of roads or railways by private sidings are generally subjected to the approval of the service affected.

In almost every instance check-rails are required to be fitted at crossings and the web of the wing-rail is secured to the stock-rail of the main track.

Cost of constructing sidings. — Private sidings are almost always installed entirely at the cost of the user, and this applies equally to the junction and to the part in the station and to that outside the Company's property.

Generally the Companies themselves make the junction and lay the part of the siding on their property, while the owners of the siding execute the part outside the Company's property. The movement of rollings stock on the siding is always subject to the approval of the representatives of the Company or of the State.

It is nearly always the case that the payment of the dues by the manufacturers or the merchants using the private siding are made in cash; a deposit is generally paid before the work is carried out and the balance is settled soon after completion. Deferred payments or annual instalments are only accepted by a few Companies.

On the other hand the portion of the track belonging to the Company is often leased by the firm served by the siding who thus make an annual payment to the Company.

Service of the sidings. — The service for the private sidings is generally performed as follows : the railway Company

ensures the supply of rolling stock at fixed rates the wagons being left at or received from the beginning of the siding which is marked by the gate and the stop block.

Some Administrations, while generally following this rule, allow exceptions in favour of certain firms with whom they have special agreements according to which they ensure the working of the whole length of the siding in return for a special charge. These special charges are based on the time the locomotive is outside the Company's property and on the time of the members of the staff engaged in the shunting operation, who are considered as being in the employ of the firm using the siding which is responsible for accidents.

These special cases are to be found on the Belgian State Railways, the French Northern, French Eastern and Orleans Railway Companies, and on the Swiss Federal Railways.

In many cases also the service is ensured either by the Railway Company, or by the firm using the siding, according to a special arrangement dependent on the particular conditions. This system is in use on the Swedish State Railways.

Commercial conditions affecting sidings. — The commercial conditions relating to private sidings while varying considerably according to the country and to the traditions of the various Administrations may be summed up as follows :

1° Collection of dues for sidings usually in proportion to the number of wagons, sometimes to their tonnage and also proportional to the length of the siding;

2° Settlement of time limits for loading and unloading, in some cases fixed and sometimes proportionate to the length of the siding;

3° Settlement of penalties in case of exceeding the fixed limits;

4° Finally (but very rarely) allowance of a bonus to the firm using the siding for expedition in clearing the wagons.

On the Belgian State Railways the sidings are divided into three categories according to the expense incurred in serving them. The rates to be collected per wagon for these different categories are determined from a table which takes into account the annual amount of traffic over the siding.

On the large French railway systems the tariffs have been merged into one which is as follows :

Siding dues : for the first km. 0.12 fr. per ton capacity of the wagon, plus 0.04 fr. per km. or fraction of a km. over the first km., these figures being subject to the usual increase :

Time limit : 6 hours for a siding 1 km. in length, plus half an hour per km. or fraction of a km. over the first km.

Penalty : equal to the siding dues for each 6 hours or fraction of 6 hours delay, including night time.

Article 6 of the special tariff by-laws P. V. 29 fixes a special rate called the « wagon rate » which must be *specially demanded in writing* by the user of the siding and which amounts to 1 fr. per wagon.

The time a wagon is left standing on the siding must not exceed 6 hours.

The demurrage in case of delay is then:

1 fr. 50 3 fr. 50 6 fr. 00 9 fr. 00	when the delay does not exceed	6 hours 12 — 18 — 24 —	night time inclusive;

and above 24 hours at the rate of 3 fr. for each period of 6 hours or fraction thereof.

The loaded rolling stock received on the siding should in general be returned empty : when the Company permits reloading the time limit is increased to 9 hours and only 1 fr. is charged of the rate for the supply of the wagon as if returned empty.

CHAPTER II

Ordinary goods yards.

Effect of the commercial conditions on the arrangements adopted. — The commercial conditions affecting the transport contracts which have just been considered undeniably have an influence on the arrangement of the tracks in the yards.

It is necessary, in fact, that a goods yard should have : covered sheds and platforms of sufficient area to receive the goods which have to be unloaded there; main sidings corresponding to the number of wagons that can be put at one time at the disposal of the public; and finally a length of secondary sidings sufficient to contain the empty rolling stock intended for loading, and for the loaded wagons in waiting to be unloaded or to be despatched. The tracks and points should also be so arranged as to make the shunting operations as easy and rapid as possible and also to avoid any delay to the public in carrying out its own operations.

We shall briefly examine the various arrangements adopted for the tracks and for the sheds with the object of best meeting these conditions.

A. — Arrangement of tracks.

Tracks arranged in X-form. Spur tracks (transverse or parallel.) — In a goods yard it is often advisable to arrange the unloading sidings in short lengths of considerable number connected to the main sidings by means of communications which are independent of each other. This arrangement enables each to have allotted to it some wagons of which the loading or the unloading will be carried out simultaneously by the same forwarding or receiving agent. These wagons may then be collected or removed without in any way inconveniencing the neighbouring operations.

These unloading sidings may be arranged according to three systems (see fig. 1) :

1° Ordinary track;

2° Covered track (unloading of wool, fish, etc.);

3° Tracks of X-form or fan-shaped, the branches of wich are served by a single turntable;

4° Tracks forming two branch spurs perpendicular to the main sidings serving them and served by a single turntable;

5° Tracks with spurs parallel to the main siding and connected to it by points;

6° Tracks with hoppers for unloading coal chiefly.

The two first arrangements have been little used up to the present; the reason for this is undoubtedly that they can only be used where the main sidings are very long and where they are necessarily fitted with check-rails to allow lorry traffic. They appear nevertheless likely to come more largely into use owing to the necessity for using every means for getting the greatest amount of work out of the rolling stock.

The fan-shaped arrangement of tracks has only been mentioned by two of the French railway systems: the Orleans Railway Company, which has an installation on the Queyries quays (Bordeaux) with a

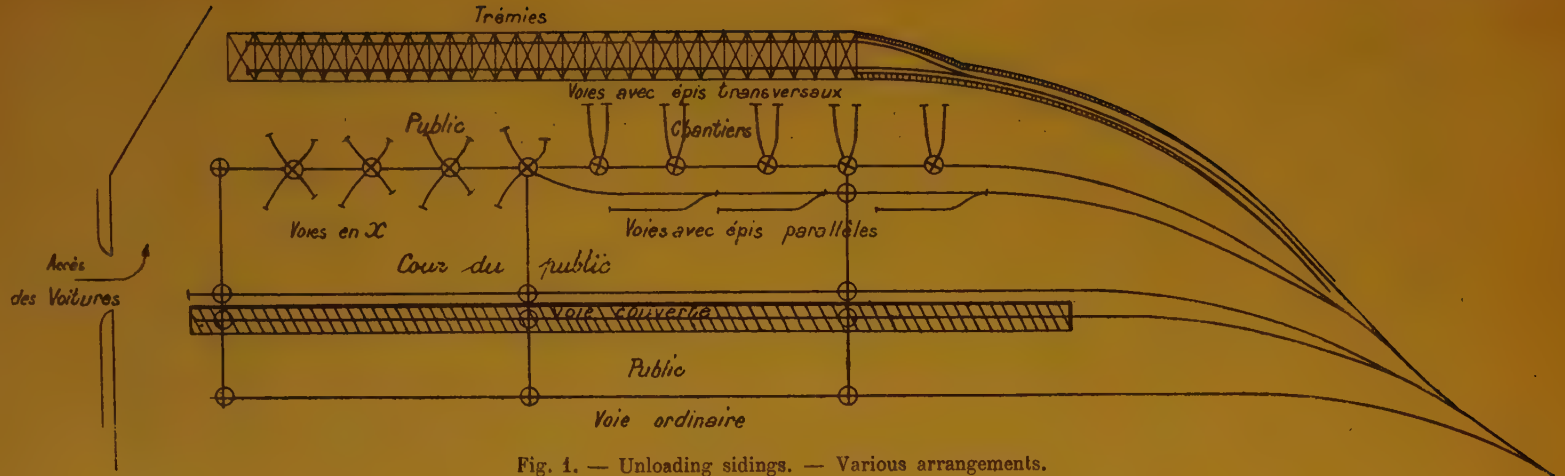


Fig. 1. — Unloading sidings. — Various arrangements.

Explanation of French terms : Trémies = Hoppers. — Public = Public. — Voies avec épis transversaux = Tracks with spurs at right angles to the siding. — Chantiers = Unloading spaces — Voies avec épis parallèles = Tracks with spurs parallel to the siding. — Voies en X = X-arrangement of tracks. — Cour du public = Public yard. — Accès des voitures = Entrance for carts. — Voie ordinaire = Railway track. — Voie couverte = Covered track.

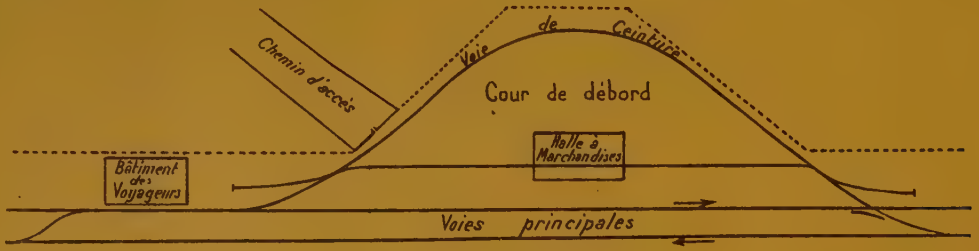


Fig. 2. — Small goods-yard.

Explanation of French terms : Chemin d'accès = Entrance to yard. — Voie de ceinture = Loop-line. — Bâtiment des voyageurs = Passenger station. — Halle à marchandises = Goods warehouse. — Cour de débord = Unloading yard. — Voies principales = Main lines of railway.

fan-shaped arrangement of tracks spreading from a single turntable; and on the French Northern Railway which has used the same arrangement at the port of Gennevilliers.

With regard to the X-form, the oldest arrangement of this class is certainly that at the Lille-St-Sauveur Station (on the French Northern Railway) which has just been rearranged as part of the scheme for the complete transformation of the yard; this has been made possible by the change in the conditions, since the war, which have allowed the fortifications that enclosed the station to be pierced.

The arrangement consists, as is shown in the figure 1, in having the X arranged with unequal branches, each served by a turntable, which is itself placed on a single longitudinal feeding siding.

The wagons to be unloaded were placed in groups of three on the two longest branches of the X situated on each side of the central feeding sidings.

The two shorter branches which were arranged in line with the longer ones were limited in capacity to holding two wagons and were used only for clearing purposes.

At the time of filling up the sidings, before the goods yard was thrown open to the public, there were therefore six wagons on each X (three on each of the long branches). As soon as the public had freed a wagon it could easily be removed without disturbing its neighbours even if it should be the end wagon.

In fact, by means of the capstan (1) serving the turntables the three wagons intended for unloading were drawn back together: the first two were thus brought on to the short clearing arm; the last wagon which had been freed was then turned on the turntable and run on the longitudinal main siding.

The operation having thus been performed from one X to another X it only remained for the shunting locomotive to collect the whole of the wagons thus freed and to take them to the marshalling sidings or to the central sidings, and then to replace them with the number of new wagons required to fill the gaps which had just been made on the arms of the X's, and so on throughout the day.

The spur tracks, when perpendicular to the service track are also not common. There are, however, some examples in Denmark and in France on the Paris-Lyons-Mediterranean system and on the French Northern Railway (1).

The arrangement most usually adopted in less important yards, for the main sidings, consists of an outer track running round the goods-yard space, of which the arrangement is generally similar to that

(1) An alternative to the fixed capstans has been very wisely adopted, with this arrangement of tracks, on the French Northern Railway consisting of a small hand-operated capstan (which itself can turn on a turntable if required); this is used to haul the wagons on to the arms of the X and to turn them on the turntable. With this appliance the operations of putting the wagons in place and withdrawing them can be proceeded with throughout the day.

(1) Installations of this kind have been tending to disappear on the French Northern Railway for the reason that it was becoming more and more frequent for the wagons to be freed all together and thus for them to be able to be put without trouble on a longitudinal main siding. This was due to the clause allowing a reduction of 10 % on the cost of transport when the operations were performed within the time limit of six hours, that is to say, practically, on the same day. The recent disappearance of this clause (under the unification of tariffs) which was very largely in force on the French Northern Railway will certainly involve recourse to the arrangements enforced before the war which had become obsolete.

shown in figure 2, whenever it is possible to connect this track by points at its two ends; this, however, is not always possible and it frequently happens that the outer tracks have dead ends.

In the large yards the most varied arrangements are to be found, but they are nearly always derived from that of parallel spurs connected to the longitudinal service siding (see fig. 1). These spur tracks are generally arranged in groups of twos or threes. The Paris-Lyons-Mediterranean Railway, which formerly used the grouping in threes now avoids this; the middle track which is not accessible to lorries can only serve as a standing or clearing siding and is usually not fully utilized.

To facilitate the placing of individual wagons or small groups of wagons on the loading or unloading tracks, right angle crossings with turntables have been largely used. At the present time there are few goods yards in France in which this arrangement is not to be found.

It is in fact particularly useful when it is necessary to connect various dead-end sidings together in one goods yard. Even when these tracks are connected by points to the main sidings at their two ends an arrangement of turntables with cross tracks placed near the middle enables the shunting of single wagons to proceed without disturbing the general arrangement of wagons on one of the tracks. These shunting operations can be performed either by the aid of horses, or other animal traction, or by means of power-supply, either electric or hydraulic.

While recognizing the general usefulness of turntables, they have also serious disadvantages :

The capacity and consequently the length of the wagons is constantly increasing, so that the turntables become too small a few years after they have been put into work.

In case of hard frost the small quantity of water which always collects in the lower part of the turntable mechanism freezes and prevents it from working.

In fact it is an appliance which is often in the way, expensive in first cost and maintenance, not always able to perform its service as it should be able to do, particularly when there is shortage of labour for the reason that it requires several men to turn a wagon on a turntable.

Finally it is obvious that on main lines the use of turntables must be absolutely forbidden on account of their mobility and of the necessity, where is express-train traffic that they should be adapted to it. For this reason in one of the roads on its upper surface the rails of the main lines must not be cut, consequently those of the accessory cross-track must be considerably raised above its level and cut with wide gaps for the main line flanges, an arrangement which destroys the symmetry of the turntable plate and requires that it shall be restored to position when empty after each operation.

Turntables are now no longer provided in the schemes for large modern yards; it is becoming more and more usual to substitute traversers worked by hydraulic pressure or preferably by electricity.

In some large yards a system of rectangular cross roads served by surface traversers has been installed.

In other stations it has been preferred to use diagonal points for dividing dead-end sidings into sections, see figure 4 (Swiss Federal Railways).

Long and continuous main sidings. — In all countries any important goods

yard comprises at least one long and continuous main siding connected by points with the main railway tracks at one, at least, of its ends.

The long main sidings are almost always arranged parallel to the main railway track, or to one side of a fan arrangement of marshalling sidings arranged between the main lines and the goods yard to which they are adjacent on their longer sides.

There is a tendency to connect, at its two ends by points, that one of the main sidings which is nearest to the main track; the other main sidings generally have dead ends and are connected to each other by turntables.

Only in important stations is use made, apart from parallel lateral tracks, of several groups of central tracks having an unloading yard on each side (French Midi Northern, Orleans and Paris-Lyons-Mediterranean Railway Companies, Belgian State and Norwegian State Railways). In this case the arrangement of the yards is often fan-shaped (French Eastern Railway).

It is very important that the long main sidings should be at least as long as the trains which the shunting engine in general use can haul.

Ratio between the capacity of the public tracks and the magnitude of the work done measured in tons. — The greater number of the railway Administrations state that they have not taken steps to establish any relationship between the tonnage of the local traffic and the capacity of the main siding — or that they have not been able to determine this owing to the variety of the traffic through the yard.

Some Administrations have however given figures as follows :

RAILWAY.	Per metre (per yard) of main siding per annum.
Spanish Northern Railway	80 wagons (73.2 wagons).
French Eastern Railway	150 to 200 t. (137 to 183 t.).
French Orleans Railway	80 t. (73.2 t.).
Paris-Lyons-Mediterranean	24 wagons or 120 t. (22 wagons or 109.8 t.).
Russian Vistula Railway	125 t. (114.4 t.).

In the preparation of the schemes for new installations the basis generally adopted is the maximum number of wagons that are required to be placed at one time on the main siding, taking the daily mean for the period when the traffic is most dense; in this is reckoned a delay, or standing time, determined by experience and by the character of the most important traffic, both for the wagons to be loaded and for those to be unloaded.

The Norwegian State Railway states that their installations are all capable of expansion and are in fact enlarged when required by the exigencies of the traffic.

Use of waiting sidings. — Almost everywhere waiting sidings are used on which the wagons are placed before they pass on to the public tracks, or after they have been withdrawn from these tracks.

Nevertheless many of the Administrations only use them in some of the more important yards, because they might be put to wrong uses. Frequently for the want of a track set apart for this work one or two of the tracks of the marshalling sidings of an adjacent yard are used as waiting sidings.

The French Midi Company has at some places waiting sidings which are used for storing tank-wagons (for petroleum, etc.).

On the Orleans Railway Company it is not considered advisable to disturb the wagons on the public sidings during the period that the yards are open to the public, and the wagons brought in by various trains during the day are shunted on to waiting sidings; similarly the wagons that have been withdrawn during the night are left on these sidings to wait for their trains. In order to do this it is necessary that a locomotive should be available at night after the yard has been closed to the public (either a shunting locomotive or the locomotive of a train passing through the station).

On the French Northern Railway some waiting sidings are conveniently connected to other tracks of main sidings by some one or other of the methods which have already been mentioned. On these partial shunting operations are carried out during stated hours for putting into place or removing wagons as between the waiting siding and the main siding or *vice versa*. This enables time to be saved for certain wagons without disturbing the public by shunting operations taking considerable time.

Use of separate yards for certain goods. — All the Administrations have, at least in the more important yards, separate spaces set apart for the loading or unloading of certain classes of heavy and bulky goods, or for heavy goods received in large quantities.

This is the case in many of the stations of France, Belgium and Spain in which there are special yards for building stone, timber in the log, marble, constructional steel work, etc.; these yards are fitted with travelling elevated or goliath cranes.

Almost everywhere there is a grouping into separate parts of wagons carrying coal, minerals, sand, etc., and other goods in bulk received in large quantities. For unloading these wagons into lorries, floats or narrow-gauge railway trucks, use is often made of raised tracks or stagings.

At various points spaces are reserved for stores of coal, sand, lime and cement which are leased to local dealers.

It is usual also to isolate inflammable goods such as paraffin, oil, etc., which are put on waiting sidings outside the warehouse on open platforms.

At the Brussels, Tour et Taxis, goods yard there are special tracks with covered platforms for unloading fish and oil; at Louvain for loading beer. The stations at Verviers and Dison have special tracks for wool.

B. — Arrangement of open sheds.

Relations between the area of platform of the open sheds and the tonnage to be handled. — The greater number of the Administrations state that they cannot give the ratio between the area of platform of open sheds and the tonnage handled because the time that the platforms are occupied and the area occupied on the platforms vary too much from one station to another, according to the predominating goods. Many railway systems have taken no steps to determine this ratio.

The mean figures quoted with some exactitude are as follows : All apply exclusively to slow goods.

RAILWAY.	Per square metre (per square foot) per annum.
Spanish Northern Railway	30 t. (2.8 t.) (22 t. [2.1 t.] only when the traffic is irregular or the stations serve distant towns).
French Eastern Railway	30 to 35 t. (2.8 to 3.3 t.).
Orleans Railway.	25 t. (2.3 t.) for stations of medium importance; 33 t. (3.1 t.) for stations of less importance.

No figure relating to fast goods traffic has been communicated to us.

Separate open sheds for arrival and despatch. Sheds with more than one floor — Almost everywhere, in those stations which have several open sheds, separate sheds are allotted to arrival and departure.

The goods yards which were installed at the beginning on railways in large towns have generally become practically incapable of enlargement, being closed in by buildings of great value the purchase of which would involve enormous expenditure. It has thus become necessary to find the most effective methods for increasing their output without increasing the ground covered, by means of a better arrangement of the tracks and of the buildings for handling the goods.

One practical method consists in increasing the capacity of the sheds and of the platforms by adding another storey.

Sheds with several storeys are as yet uncommon in France and on the Continent; a few examples exist on the French Eastern, the Orleans (see fig. 3 *a*, *b*, *c*), on the French Northern and on the Paris-Lyons-Mediterranean Railways. There is a single warehouse of more than one storey at the Marseilles-Messageries goods yard; but, on the Paris-Lyons-Mediterranean Railway system, attention is now being given to erecting modern buildings of the high-speed pattern with a view to the ultimate use of a second storey.

Warehouses with more than one storey are doubtless likely to become more and more common; as in the case of those with a single floor and it is advantageous to divide them into arrival and departure sheds. In all stations having several warehouses the slow and fast goods services are kept separate.

The various arrangements of warehouses in relation to the tracks. — On the majority of railway systems the warehouses are arranged parallel to the main line and in line with each other (see fig. 4).

In some of the large stations (French Northern and Orleans Railways), there are several lines of warehouses.

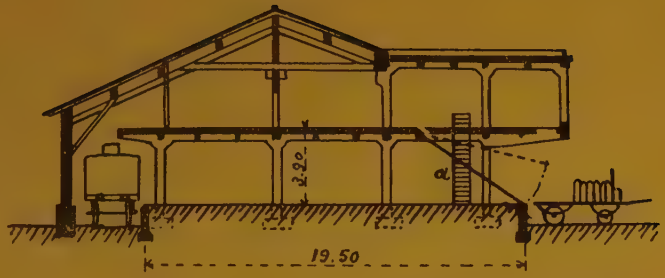
Some Administrations have an arrangement of warehouses with platforms arranged in stepped form in the large yards (Danish State Railways, Andalusian, Spanish Northern, French Eastern, Orleans and Swiss Federal Railways). The Orleans Railways system states that in its case the arrangement is an old one, which is being given up because it impedes the movement of the wagons from one warehouse to another.

On the Paris-Lyons-Mediterranean Railway the warehouses are generally arranged in line. Nevertheless at Bercy station there exists an example of an arrangement of warehouses at right angles to the main track, but this is an old arrangement which it is not intended to repeat.

Method of division of warehouses used both for arrival and despatch. — Some Administrations state that they do not allot separate portions of the same warehouse to arrivals and departures (Belgian State Railways and small stations on the Norwegian State Railways).

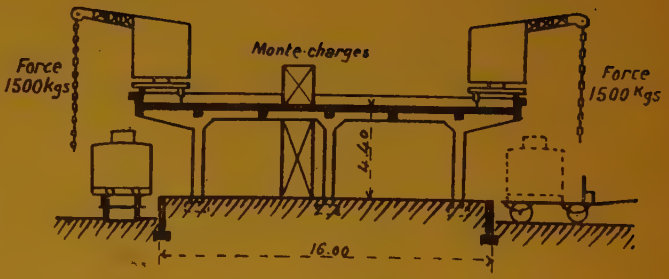
In all other places the arrivals and departures are separated. In some instances the division of the warehouse is longitudinal which requires that the warehouse should have a yard on each side or that the track should be inside the warehouse; but more generally the division is made transversely to the warehouse the one end being reserved for arrivals and the other for departures.

On the French Northern Railway Com-

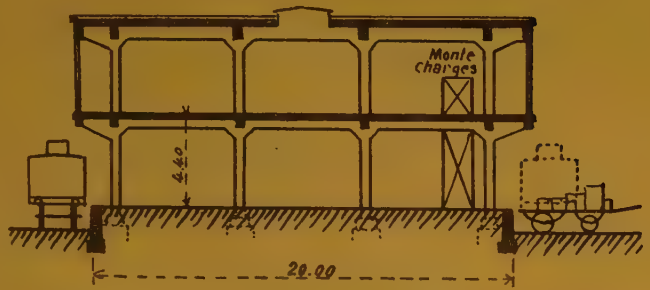


a = Inclined canvas conveyer (lifting) belt.

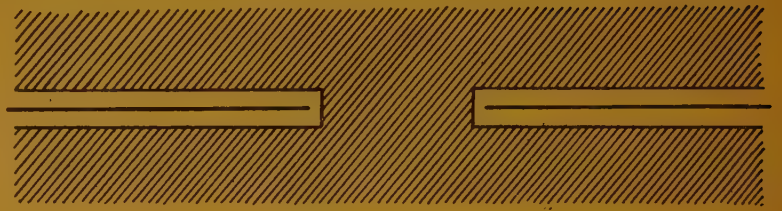
(a) Section of the grain warehouse at Ivry station.



(c) Section of the wine-quay at Ivry station.



(b) Section of the Customs warehouse at Ivry station.



(d) Transshipment warehouse at Toulouse. (Interrupted centra track.

Fig. 3.

Explanation of French terms : Force 1 500 kgs = Load 1 500 kgr. (1.5 ton). — Monte-charges = Goods elevator.

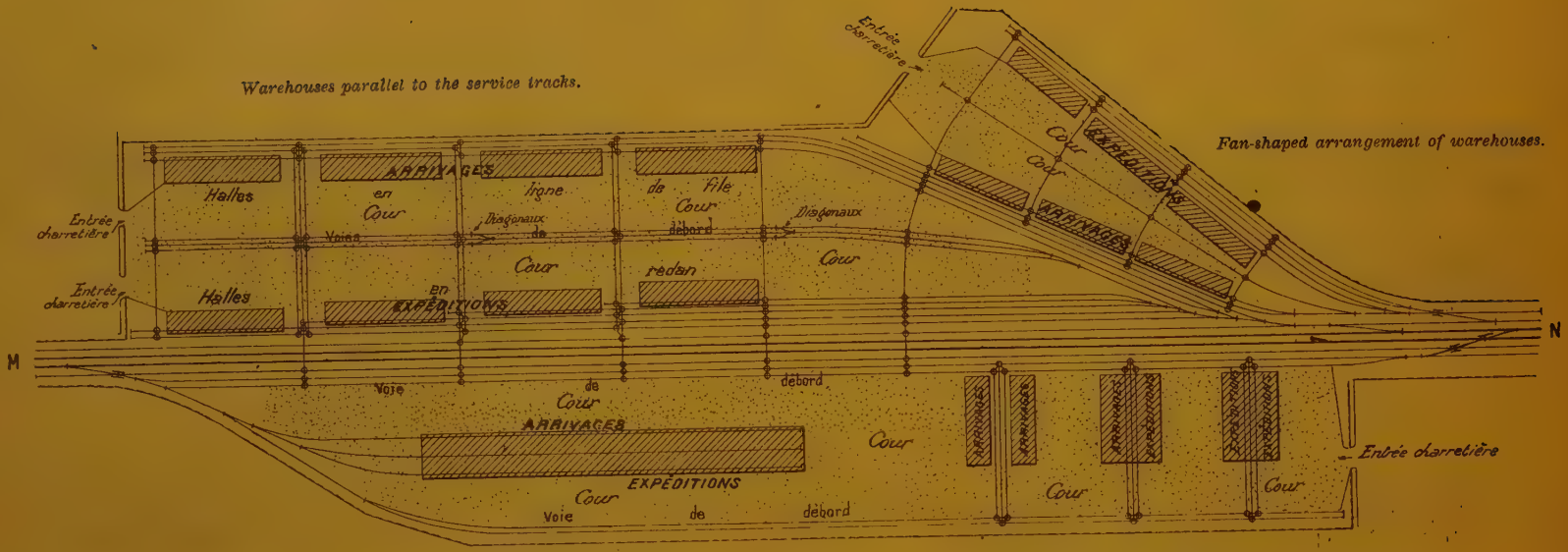


Fig. 4. — Group showing the various arrangements adopted for goods warehouses.

Explanation of French terms : Arrivages = Arrival. — Expéditions = Despatch. — Cour = Yard. — Voies de débord = Unloading track. — Halles en ligne de file = Warehouses arranged in line. — Halles en redan = Warehouses arranged in step-form (redan). — Entrée charretière = Cart-entrance. — Diagonaux = Diagonal points (cross-overs to centre track).

pany in some large stations (Lille-St.-Sauveur for example) goods are loaded direct in the evening from the lorry on to the wagon when being despatched to some of the important stations.

The large despatching firms are agreeable to this arrangement and it is to their advantage when there are trains that will remove the wagons the same night.

Arrangement of the tracks serving the warehouses. — In most cases an arrangement is adopted of warehouses with lateral tracks running along the whole length of the warehouse, either on one side only (preferably inside) or on both sides, one of the tracks in that case being placed outside the warehouse alongside the public yard and fitted with checkrails.

Apart from trans-shipping warehouses those with a central track are the exception, but they are coming more and more into use on the French Northern Railway system.

On those tracks which run through the warehouses it is possible to carry out complete or partial shunting operations, during the course of the day. Generally, even in the case of large stations which have separate warehouses for arrivals, the internal track is fed continuously from one end and the unloaded wagons are drawn away as fast as they are cleared.

When the track runs alongside the warehouse, on the outside (next to the yard) it is, on the other hand, necessary that shunting operations should not be performed during the time for which the yard is open to the public, because during that period lorries and carts are standing on the track, which, as we have stated, is fitted with check-rails.

Trans-shipping from one wagon to another wagon in the warehouse. — When it is not a very big operation, trans-shipment of merchandise from wagon to wagon is carried out in the ordinary warehouses, the packages being rolled along the edge of the platform from one wagon to the other.

When it is warranted by the amount of the traffic special warehouses for trans-shipment are used almost everywhere. These warehouses, in most cases, are equipped with two tracks inside the building and on opposite sides of the platform; the goods taken from the wagons standing on one of the tracks are divided while crossing the platform amongst the various empty wagons standing on the other track so that the packages are grouped either according to their destination or according to the line they are to take.

In the case of the separate warehouses of very large stations, in order to increase the number of wagons that are being used for trans-shipment simultaneously, it is sometimes found necessary to instal central tracks as well; these are sometimes, two in number (French Eastern, French Midi, French Northern Railways). The French Eastern Railway Company has adopted this arrangement in its new installations (the large sorting yards at Lumes and at Blainville). At Toulouse the French Midi Company has adopted an arrangement of interrupted central tracks allowing communication between the two platforms (fig. 3*d*). The French Northern Railway Company has endeavoured to obtain this communication by the use of draw-bridges arranged at intervals on the length of the central tracks (at Hirson for example).

Trans-shipment is also done partially on the tracks outside the warehouses when a train is stopped. For this purpose small movable gangways are placed from wagon to wagon standing on two adjacent parallel tracks.

Arrangements made for reloading the wagons at the same place as that at which they were unloaded. — In small yards the loading of a wagon is effected immediately after it has been unloaded. In large yards this result can be obtained fairly in the special trans-shipment warehouses.

Where there are separate warehouses allotted to arrivals and departures respectively it is not possible to carry out loading and unloading in the same place. As soon as the wagons are cleared they must proceed from the arrival warehouse to the despatch warehouse either by being hauled as trains or moved separately, the transverse tracks being used if necessary.

The arrangement of separate warehouses in line with each other is the most advantageous from the point of view of keeping down the shunting operations. By this arrangement it is possible to ensure a continuous passing on of the wagons from one warehouse to the other (Orleans, French Northern Railway, etc.) and to obtain a large output from the installations in use.

In the case of warehouses with a central track dividing them longitudinally into two separate parts for arrivals and departures, it is not necessary that the wagons should be moved: after being unloaded on the arrival side they may be immediately afterwards reloaded on the despatch side.

C. — **Installations of handling machinery.**

Machines used for handling goods and wagons. — Those railway systems which have important traffic use almost all the appliances mentioned in our list of questions: winches, capstans, fixed and movable cranes, etc., operated either by steam, or by electricity, at least in the more important yards. In almost all cases hand cranes at least are provided, or blocks and falls are fitted under the warehouse roof in yards of secondary importance.

In important yards goods lifts and also electric transporters are used in some places.

No very definite statement is obtainable as to what amount of traffic is considered necessary to justify the use of steam, hydraulic or electric plant. Usually, in designing any mechanical installation, the economy, which it will be possible to effect on the expense of handling by the ordinary methods is calculated, and the installation is proceeded with if the probable economy meets the charges (interest amortization, cost of electric cables, cost of current, etc.).

The Paris-Lyons-Mediterranean Railway Company add that, in some yards, considerations of rapidity of working and increase of power take precedence over the question of economy.

There is also no general rule governing the arrangement of the handling appliances on the tracks. In the case of travelling overhead goliath cranes it is usual that special space should be allotted on account of the great bulk of the goods handled and the length of time required for handling them which must not be interrupted by shunting operations.

With regard to capstans we may quote, as fairly general practice, the method of use mentioned by the Orleans Railway Company.

The capstans are arranged at the main crossings of the transverse tracks served by turntables and particularly where one at least of the serving tracks runs through the warehouses.

The distance between two successive transverse tracks, usually spaced 80 to 100 m. apart (260 to 328 feet), corresponds approximately to the length of cable used

and consequently to the radius of action of the capstan.

The capstan of any particular transverse track can be used for intermediate tracks by means of dummy capstan heads, for obtaining change of direction of the cable, arranged to allow for all movements of the wagons on each side of the transverse track in question and also from this transverse track to the adjacent transverse track.

Frome the point of view of output the most efficient machine to instal in a large goods warehouse appears to be an electric overhead crane with pivoting arm, an arrangement which is not common in workshops, but which is particularly useful in a warehouse having a number of columns. The pivoting arm, it is true, increases the weight of the crane and also its first cost; but it enables the distance run by it to be reduced and it extends its area of action outside the line of rails on which it is run and beyond the columns supporting its track.

Goods warehouses with several storeys are easily worked by means of such appliances : on the ground floor the handling may be done by ordinary hand wagons (moved by man power or hauled by tractors); for transfer from one to another of the floors of the warehouse the goods deposited from the wagons on the arrival platform are lifted by the first pivoting arm of the travelling crane (inside the yard) and raised to the floor required, whether by reason of the character of the goods or because the lower floors are already filled. When the consignee comes to take delivery the other pivoting arm of the travelling crane serving the opposite side of the warehouse lifts the goods and lowers them on to the platform on the public side of the yard whence they are loaded on to the lorries or other vehicles for removal.

According to the space available the travelling crane remains stationary opposite to the wagon that is being unloaded or it is run along the length of the warehouse to where there is an empty space suitable for receiving the goods to be placed on that floor. Finally, the warehouse may be fitted with a number of travelling cranes, determined by its length and by the requirements of the service, each working over a limited range.

This arrangement is reversible and may work successively as a departure and as an arrival warehouse if the working of the goods should so require.

Mechanical handling of goods in the warehouses. — Mechanical handling of goods in warehouses is at present very little in use.

On the majority of the railway systems barrows, hand wagons, Nepveu movable cranes or hand-operated runways are used exclusively.

Some administrations, however, have special high-efficiency installations in the more important yards for reducing the amount of hand labour. As examples we may mention :

1° Sliding ways, elevators and endless-belt transporters for warehouses of more than one storey (French Eastern, French State, French Northern, Orleans and Paris - Lyons - Mediterranean Railways). These appliances are used particularly for handling grain;

2° Mechanically operated appliances for loading hogsheads of wine into the wagons in two superposed lots (electric travelling cranes on the edge of the platform at Beziers and Narbonne on the French Midi Railway System; movable electric lifts at Mazamet and St-Amans-Soult on the same railway system for stacking bales of hides and wool);

3° Electric and hydraulic goods lifts are used at some places for luggage and mails; elevators, electric transporters with endless canvas belts are used at the cloak rooms at the Marseilles, Paris-Orsay stations, and elsewhere often in combination with mechanical traction by tricycle or by automotor truck.

Amongst the most modern and the handiest of the latter machines must be mentioned the electric automotor truck with accumulators the use of which has extended very rapidly during the last few years, first in the United States and then in England and, during the war, in France. Figure 5 (*a, b, c, d)* shows two patterns of automotor truck the one being a tractor only and the other a carrying truck.

The usual type of truck has four-wheel steering and two wheels driving. The truck may be an automotor carrying truck (5*a*, 5*d*) or sometimes only a hauling truck (fig. 5*b*). In the first case the accumulators are contained in front and below the chassis, in the second they take up the whole of the chassis space, leaving room only for the driver's seat. The dimensions of the chassis are approximately 1 m. (3 ft. 3 in.) wide by 2.50 m. (8 ft. 3 in) long. The accumulators are generally of the Edison (iron-nickel) type.

An interesting variety of this type is the elevating platform wagon (fig. 5*d*) which is fitted whith a vertical movement to the chassis so that a rolling platform loaded with goods can be raised and deposited in any desired place; the tractor returning with an empty platform takes back a full one which has been loaded in the meanwhile. This arrangement has been tried with success at the Paris Austerlitz station on the Orleans Railway.

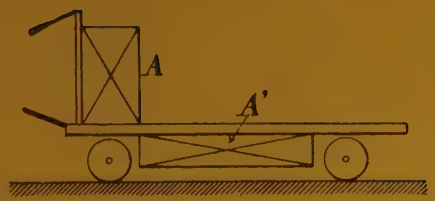
The same type of electric truck with some alteration may be converted into a crane truck, useful for loading and unloading covered goods wagons the interior of which cannot be reached by either ordinary or travelling cranes. Figures 5*e* and 5*f* show how these operations can be performed.

In working out an installation for mechanical handling it is not sufficient to consider the immediate end to be attained; it is also necessary to consider the connexion it will have with the existing installation, with the services that will affect its working, with the changes that it may require, either in the yard in question or in the rolling stock, etc. Regularity of output is important to ensure efficiency; when the nature of the operation tends to prevent this continuity it may be necessary to provide means, such as storage depots for regulating the output. It is always well to use a system of classification by density, when the arrangement of the yard permits. It is also necessary that the training of the staff should be carefully watched, because the employees are usually hostile to the use of new appliances even when the improvements tend to reduce manual labour and fatigue.

Arrangements for rapid handling of certain classes of goods such as coal, sand, grain, etc. — For the rapid handling of goods such as coal, sand, grain, etc., which give rise to large streams of traffic special installations have been arranged at certain points to enable a large output to be obtained and the rolling stock to be cleared more rapidly. Among others the following may be mentioned :

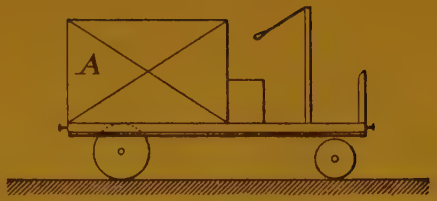
Lateral shoots used for coal in many yards generally privately owned.

Overhead stagings with hoppers installed by the railway companies themselves



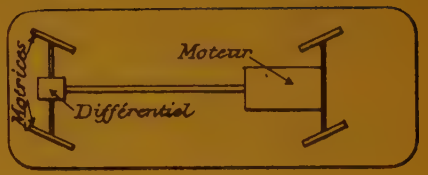
A, A' = Accumulator boxes.

(*a*) Side elevation of an automotor carrying truck.

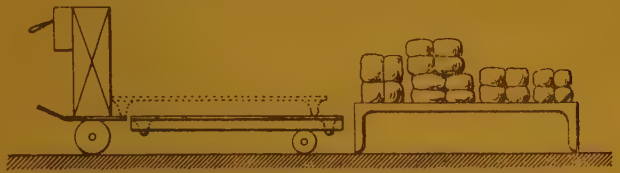


A = Accumulator boxes.

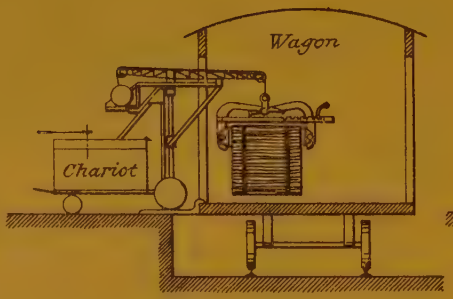
(*b*) Side elevation of automotor tractor.



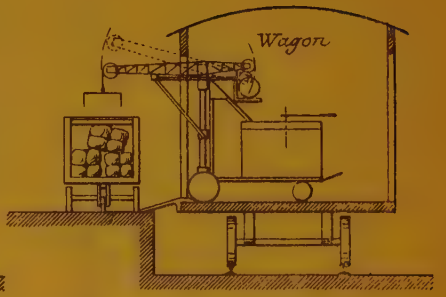
(*c*) Plan of 4-wheel automotor truck.



(*d*) Side elevation of automotor truck with mobile platform for raising platforms loaded with packages.



(*e*) Section showing loading of the inside of a wagon by an automotor truck fitted with a small crane.



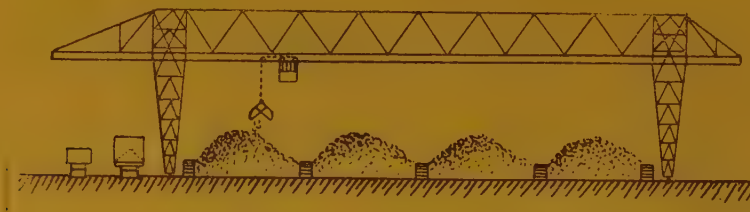
(*f*) Section showing unloading from the inside of a wagon by the same automotor truck.

Fig. 5. — Mechanical handling in the warehouses.

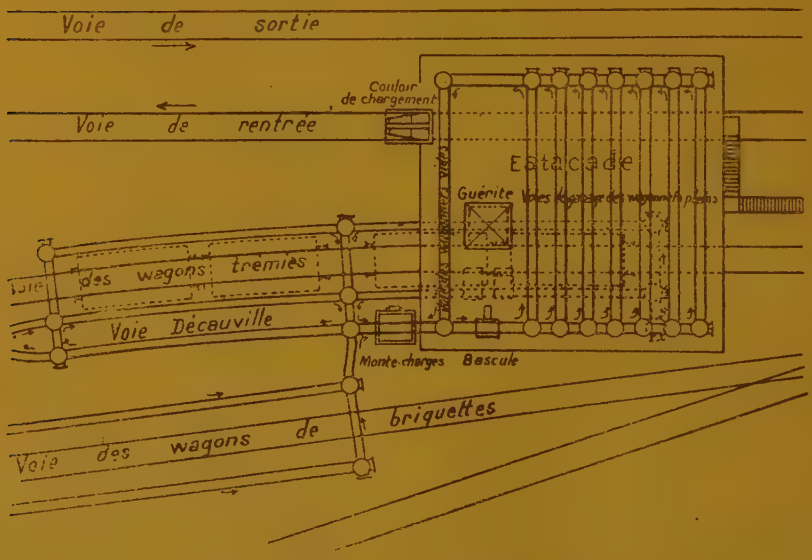
Explanation of French terms : Différentiel = Differential. — Moteur = Motor. — Motrices = Driving wheels. — Wagon = Wagon. — Chariot = Truck.

or by the Chambers of Commerce in certain yards (see fig. 1).

Gear for tipping narrow-gauge wagons into normal-gauge wagons designed by the French Midi Railway Company for Villefranche-Vernet-les-Bains.



(*a*) Section of gantry for the service of large yards.



(*b*) Plan of the staging at the Orleans yard.

Fig. 6. — Mechanical handling of fuel in the Orleans Railway Company's yards.

Explanation of French terms : Voie de sortie = Outward track. — Voie de rentrée = Inward track. — Estacade = Staging. — Guérite = Shelter. — Voie de garage des wagonnets pleins = Tracks for receiving full narrow-gauge trucks. — Voie des wagons trémies = Track for hopper-wagons. — Voie Decauville = Decauville track. — Voie des wagone de briquettes = Track for briquette wagons. — Monte-charges = Elevator. — Bascule = Tip. — Couloir de chargement = Loadingway.

Mechanical handling of coal and mechanical filling of the tenders of locomotives at some of the locomotive yards (Orleans and French Northern Railway).

On the Orleans Railway the problem to be solved not only consisted in reducing the first cost of handling, while increasing the rapidity of loading and the capa-

city of the stock; but it was necessary, on the other hand, to combine this scheme with the enlargement of the buildings and tracks of the depot in as economical a manner as possible. This result was obtained by dividing the coal storage space, properly so called, from the special installation for loading the tenders. By this means the old coal storage space was rendered available for the enlargement of the tracks and standing sidings.

The coal storage space which is of elongated shape is served over the whole of its area by a travelling gantry fitted with a grab (fig. 6*a*) which enables it either to effect the unloading of wagons arriving from the coal mines, or from the seaports, or to load special wagons, known as hopper-wagons with fuel picked up from the storage on the ground or taken out of wagons that have arrived. All the movements of the travelling gantry and of the grab are controlled by electric motors.

The hopper-wagons, after they have been loaded leave the coal storage space and are taken to the installation for filling the tenders of the locomotives. This consists mainly of raised staging (fig. 6*b*) placed alongside or above the arrival track of the locomotive sheds. By simply opening a trap-door the coal is emptied from the hopper wagons into small Decauville narrow-gauge wagons which are lifted on to the staging by means of an electric elevator. From the staging the coal is tipped into the tenders direct from the narrow-gauge wagons.

On the Northern Railway of the Russian Empire, before the war, special pumps were used for loading petroleum.

At Tourcoing, Roubaix and Saint-Denis (French Northern Railway Company) stagings of metal or reinforced concrete are used for unloading the coal. The dealers each use one or more hoppers for the coal they receive. The Company performs the unloading of the wagons when they arrive (generally at night) for a charge, and the consignee can come and load his lorries very rapidly by opening a slide or if he wishes he can mix the coals by opening two shoots on to the same lorry.

At other places goods are tipped into storage hoppers for subsequent loading on wagons.

At the port of Marseilles there are hopper appliances for filling the grain into sacks.

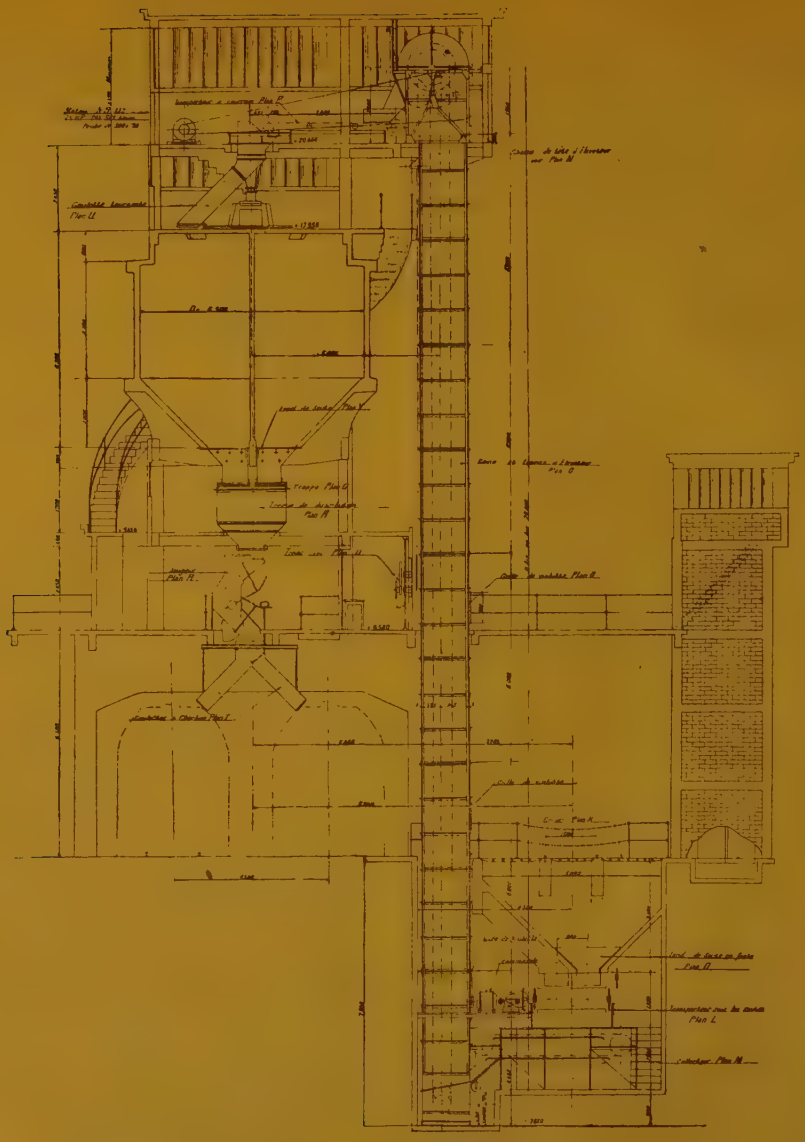
On the Norwegian State Railways there are appliances for loading pyrites.

The capacity of the hoppers varies; on the French Northern Railway hoppers are used of 30 to 40 tons capacity each being divided into two by a vertical partition in the case of coal hoppers.

On the French Northern Railway, on which the tenders of the locomotives were loaded mechanically before the war, still more powerful mechanical installations have been adopted for the large depots now in course of construction at the big railway stations that are being remodelled.

The fuel arriving from the coal fields, or taken from the stock on hopper wagons, is discharged on a special track (K), into hoppers (D) (fig. 7 and 8) whence it is carried by an endless conveyer belt which drops it into a central well. A belt takes it thence and tips it into the lower part of a vertical bucket-chain elevator.

At the upper part of this bucket-chain the fuel is directed by a movable shoot, according to its class, into one or other of the bins, each of 40 m^3 (1 400 cubic feet) capacity, which are adjacent and so arranged that they can be emptied singly or simultaneously (for making mixtures) into a distributing hopper from which a

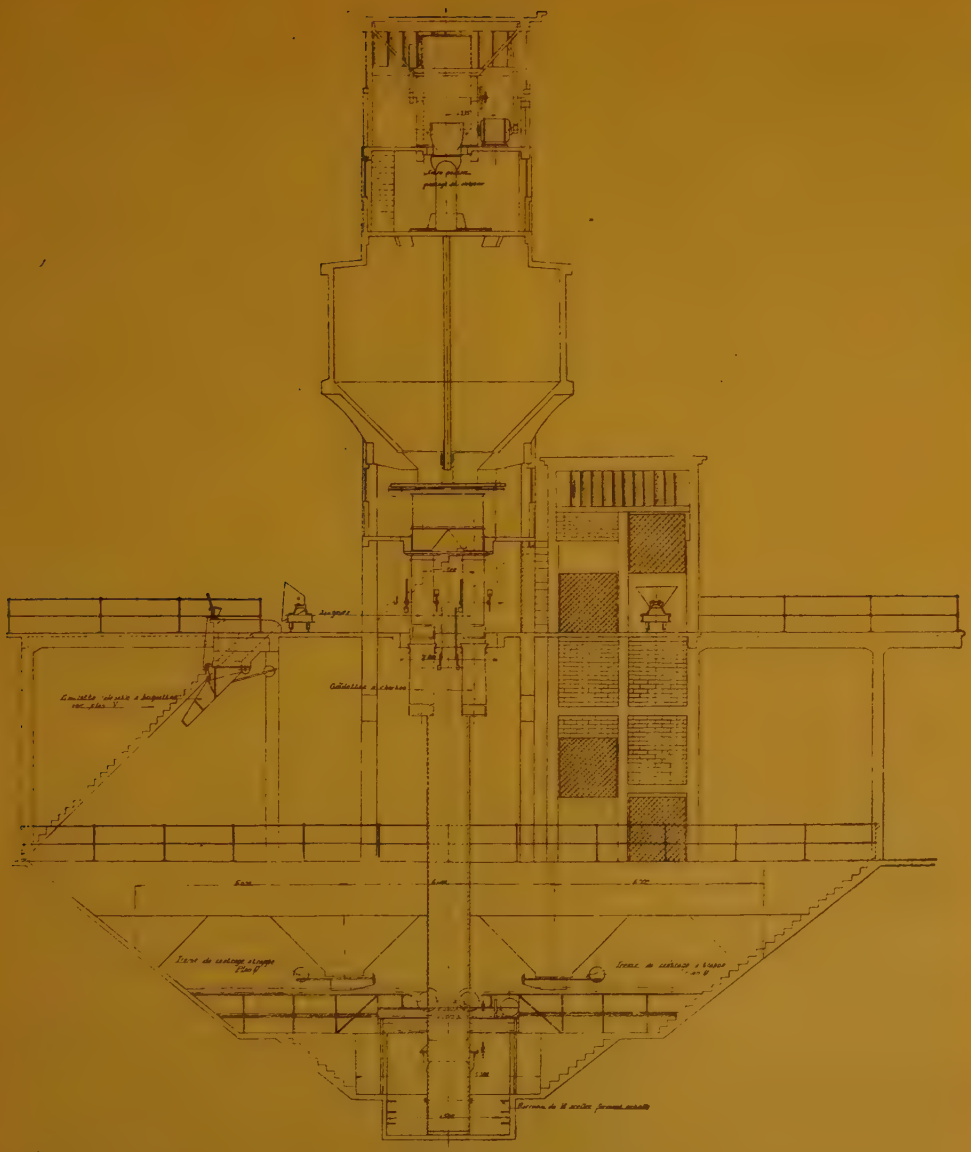


Elevation, part section.

Fig. 7. — Handling of coal and briquettes. — Output 100 tons per hour. — General arrangement.

Explanaton of French terms of figures 7 and 8 :

Motor N. R. 132 25 HP 965-982 tours. Poulie de 300 × 150 = 25 H.P. Motor (N. R. 132) 965-982 revs. per min. Pulley 11 13/16 × 5 15/16 inches. — Transporteur à courroie = Conveyor belt. — Châssis de tête d'élévateur = Elevator head frame. — Goulotte tournante = Revolving shoot. — Fond de soute = Bunker bottom. — Gaine et tension d'élévateur = Cover and tension frame of elevator. — Trappe = Trap-door. — Trémie de distribution = Distributing hopper. — Treuil = Winch. — Jaugeur = Checker (meter). — Grille de visibilité = Inspection grating. — D'axe en axe = Centre



Side view, part section.

Fig. 8. — Handling of coal and briquettes. — Output 100 tons per hour. — General arrangement.

Explanation of French terms of figures 7 and 8 (continued) :

to centre. — Goulottes à charbon = Coal shoots. — Grilles = Gratings. — Commande = Driving motor. — Fond de soute en fonte = Cast-iron bunker bottom. — Transporteur sous les soutes = Conveyor below bunkers. — Collecteur = Collector. — Entre poutres = Between girders. — Passage de l'élévateur = Opening for elevator. — Goulotte relevable à briquettes = Lifting shoot for briquettes (see plan). — Trémie de centrage à trappe = Centring hopper with trap-door. — Barreaux de 18 scellés formant échelle = Bars (18 mm.) built in to form a ladder.

movable shoot reaches to a point above the templet of the tenders.

Wagons containing briquettes are placed upon a special unloading track and are unloaded on to small narrow-gauge trucks. The latter are raised by an elevator and run to a shoot, which can be raised, by means of which the contents of the trucks can be loaded on to the tenders.

This installation is run electrically and is capable of handling 100 tons per hour.

CHAPTER III

Seaport tracks.

A. — Administrative system.

In the Administrative system of railways at seaports differences are to be found in all countries, and even in the same country, according to the date at which the railways were constructed or the concession was made.

Most of the companies have no tracks exclusively set apart for the transport of passengers in the port with the exception of Calais Maritime station to which the French Northern Railway has prolonged its mixed traffic line between barriers through the port up to the station at which the passengers are embarked and disembarked.

In France the railway tracks in non-specialised ports have generally been installed, either wholly or partially, at the expense of the Chambers of Commerce; the railway company assures working and maintenance and generally remits to the Chamber of Commerce a fixed toll per passenger and per ton of excess luggage.

At the ports served by the French Railway system the sub-structure of the tracks on the harbour property is carried out by the State with the assistance of the Chamber of Commerce, the Railway being responsible for the super-structure and being alone responsible for working. The railway system nevertheless levies a charge on a large number of classes of goods of traffic on the tracks of the port.

The railways in the French ports are generally the subject of particular concessions which were settled under the conditions laid down in the laws dated 11 June 1880, relating to light railways and tramways. Nevertheless in some cases the tracks have been installed as an extension of the general railway system (Ports of Redon, Javel, Cette, St. Louis du Rhône).

Article 46 of the law dated 31 July 1913, which supersedes and revises the law of 11 June 1880, decides that railway tracks in ports, when they are not of the type of a private siding, are subject, from the point of view of the concession and of the financial scheme, to the same rules and regulations as the main or light railway tracks to which they may be connected.

The special concessions which were given under the name of port railways therefore continue to exist, but their incorporation with the earlier concessions of which they are an extension has been recognised by the law after having been realized by necessity.

In Russia and in Sweden the tracks in seaports generally form a portion of the main railway system.

Administrative and commercial system for private sidings in seaports. — A large number of Administrations have no private sidings in the seaports. This is the case with the Belgian State Railways, the Andalusian Railway and the Algerian Railways.

All those Railways which have private

sidings in the seaports (and in particular the French Railway Companies) answer almost unanimously that the administrative system applied to these sidings is analogous to that for private sidings connected direct to the main line; it is determined in each port according to article 26 of the special act of concession for the tracks in seaports.

In France an order by the Prefect may intervene to authorise private sidings in the ports (whereas the ordinary sidings connected direct to the general railway system must be authorised by the decision of the Minister). The order by the Prefect contains conditions analogous to those of the decision of the Minister, but in addition it decides certain points definitely relating to the movement on the tracks of the port of wagons intended for the sidings, the hours of service of the sidings (morning and evening), etc.

Movement of the rolling stock. Making up and dividing trains on the tracks of seaports. — On certain points the replies are almost unanimous in stating that the ports have no individual authority in the movement of the rolling stock and that they are, on the other hand, attached to a neighbouring railway station which forms part of the main line with which they are connected by local shunting operations.

The Belgian State Railway states, however, that the port of Antwerp has a separate existence and that it is served by several railways stations for the making up and splitting up of the trains.

On the Railways of the French Midi and Orleans Companies trains are only made up and split up on the tracks of the seaport under exceptional conditions.

On the Russian Nicholas Railway, before the war, the seaports had a separate existence and carried out the making up of trains themselves.

On the French Northern Railway also, where however the installation of tracks in the seaports is the subject of special peculiar concessions to the Railway Company, apart from the main line, it is considered that the shunting sidings should form, so to speak, an integral part of the port itself.

It is necessary in fact that the goods when once loaded at the port should be removed in as nearly as possible a continuous manner, as they arrive, by simple shunting operations along the sidings to be made up in the marshalling yard into trains. They should proceed uninterruptedly, being arranged by destination when they are taken over the distributing points at the head of the sidings on which the geographical classification of the components is effected in making up the train.

This is the only method that enables all the units taken at the port to be collected together in the minimum of time and by a continuous process without any forward and backward movement. The shunting locomotives which have thus brought the wagons to the departure track do not go back light to the yard from which they came; for they take back from the arrival tracks alongside, on which the dead trains are standing that have returned from the railway system, either a batch of wagons full of goods for exportation or one of empty wagons for use at the importation berths.

Whereas, on the other hand, if the group of shunting sidings is very far away from the sidings in the seaport which feed it, it is necessary to make up proper trains running between the yard and the

port and this results in making successive groupings in the course of running. This delays the turnover of the rolling stock and gives rise to considerable losses of time and to heavier expenditure on locomotives and staff; whence a considerable reduction in efficiency arises both in time and in costs of working.

Commercial measures used for facilitating the expansion of the traffic in seaports. — To encourage development of the traffic special tariffs for export and transit have been put into force almost everywhere which afford large reductions. Nevertheless the Danish State Railways, the Andalusian and the Algerian State Railways state that they have adopted no special tariff.

Clauses in the tariffs tending towards accelerating the operations of handling and hastening the turnover of the rolling stock are rarely to be found. The operations of loading and unloading are, in nearly every case, subjected to the ordinary regulations (Danish State Railway, Andalusian, Spanish Northern, Paris-Lyons-Mediterranean and Norwegian State Railways).

On the Orleans, the French Northern, the Bona-Guelma (Tunisia), and on the Nicolas Railway (Russia), on the other hand reduced tariffs are (or were) in operation for hastening loading and unloading in order to quicken the turnover of the rolling stock.

On the Norwegian State Railways reduced tariffs have been applied, generally under the condition that the shipments will be equally distributed over the whole year.

B. — **Arrangements of tracks and buildings.**

Methods of storing goods during the time that elapses between transport by rail and transport by sea. — In order to obtain the necessary equalizing arrangements necessary to cover the irregularity of sea transport and the continuous flow of traffic by railway the same methods are almost universally used.

Behind the tracks at the platforms open level ground of sufficient area is arranged on which goods can be stacked in the open, or buildings are erected, sheds, warehouses, silos, etc., which belong to the Chambers of Commerce and to individuals.

The exporters therefore discharge their goods on the quay to wait for the ships which will receive them.

In the case of goods imported it is also the practice to make large stores on the ground of such materials as wood, cotton, raw wool, etc. In the case of some goods the consignees have to perform certain operations on the platform before loading them on to the wagon : such as acceptance, sampling, etc. In the private stores, belonging to the Chambers of Commerce and to individuals, the goods may wait a longer time according to the fluctuations of trade and the handling or grouping to be effected.

With regard to this it is necessary to draw a clear distinction between imported and exported goods.

By reason of the traditional liberty allowed to those using the ports these individuals have often abused the facilities by encumbering the ports with imported goods which have required to undergo detailed checking by the Customs, or which, owing to their not having been sold, remain there for a long time waiting for the purchaser. It thus happens that little space is left for the goods to be exported, which require the use of the quays at the proper time to enable them to be loaded without delay as the

return freight for the ships that call, as soon as these have been cleared of imported goods. This is essential in order to reduce the time of the ship in port to a minimum.

It is therefore necessary that in seaports, apart from the jetties which are directly accessible to the ship, there should be provided at the back public or private warehousing establishments managed by the Chambers of Commerce or by individuals in which imported goods that have to undergo sampling or slight change before becoming saleable may be placed as soon as they arrive. The transport to these warehouses at the back of the docks may be easily done by sailing barges brought alongside the ships (with a floating crane between) in such manner that the goods to be transferred may be discharged into them : at the same time on the other side of the ship direct trans-shipping takes place on the track alongside the quay by means of the lifting appliances with which the port is equipped of goods which can leave immediately in wagons.

While the wagons loaded with the latter goods are drawn away direct to the shunting sidings and to the railway the sailing barges or lighters which have been loaded on the other side of the ship are taken by canal to the yards at the back of the docks. These yards are themselves served by auxiliary tracks which allow the wagons to be removed at the proper time into the shunting sidings where they are made up into the trains.

The Railway Companies for their part take care always to have ready a sufficient quantity of empty rolling stock for receiving the goods imported and enabling them to be discharged direct from ship to wagon. The Navigation Companies consequently give notice to the railway companies to make provision for the arrivals of the ships (1).

It is frequently the case (particularly on the Belgian State Railways) that the whole or part of the charges due to material standing waiting for the boats should be remitted.

The Orleans Company proposes to establish « silos » (2) for minerals to be exported from the new quay at Roche-Maurice (Port of Nantes).

Before the war the Nicholas line (Russia) had grain elevators and numerous warehouses at the « New Port » which were capable of receiving a daily delivery of 300 wagons of grain for export.

Various arrangements of tracks in the ports. — In almost all ports a series of tracks running along the edge of the quays has been arranged; the track nearest to the edge, known as the quayside track, being generally used for handling those goods that can be unloaded direct from ship to wagon or *vice versa*. One track (or sometimes two) adjacent to the quayside track is reserved for the wagons waiting for loading or for hauling away, before or after being run on to the quayside track. Finally the third or fourth track inwards from the edge of the quay forms the edge of the level spaces or warehouses and receives those goods that have

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(1) The use of wireless telegraphy now enables notice to be given so long in advance that with care it is possible to adjust the arrival of goods to that of the ships. This causes an economy in the supplementary handling which is involved when goods have to be put into store or warehouse while waiting.

(2) The French term « silo » is used not only for an airtight store for agricultural produce, but sometimes, as in this case, for a broad trench served by a travelling gantry crane. (See fig. 11. type 3.) [*Translator's note.*]

to be handled: for acceptance, weighing, filling into sacks, etc. Suitable connections by points or turntables are arranged between these various tracks.

Except on the French Northern Railway the marshalling and splitting up of trains is seldom done in the vicinity of the quays where all the space should be kept clear for the operations of handling goods. The groups of shunting sidings are generally arranged at some distance from the docks between the main railway line and the port.

At the Queyries quay at Bordeaux there is a fan-shaped arrangement of tracks served by a crane.

The Orleans Company is studying the enlargement and the complete transformation of the tracks and of the equipment of the port of Roche-Maurice, on the right bank of the Loire, below Nantes (see fig. 9).

This port is actually equiped with :

1° above the small village of Roche-Maurice; 4 berths which serve for unloading coal and for loading minerals;

2° below this village; two stagings for cranes served by 3 tracks on the quay about 380 m. (1 250 feet) in length connected by turntables alongside which there is a through track.

The new scheme comprises :

1° above Roche-Maurice; the transformation of the 4 existing berths;

2° below Roche-Maurice, the making of a row of 10 berths;

3° the removal of the marshalling yard at Chantenay up-stream in line with the 10 new berths;

4° later, the construction of large warehouses in connection with the new berths.

The 4 up-stream berths will be devoted to the unloading of minerals, coal, phosphates, pyrites, which can be handled by automatic grabs and conveyer belts whereas the ten down-stream berths will serve for the transit of various goods.

At each of the 4 up-stream berths a rectangular storage ground will be provided served by a travelling gantry crane of 35 m. (115 feet) span; the coal unloaded by the cranes at one berth on to a first collecting conveyer belt passes thence to a distributing conveyer belt and then on to that of the travelling gantry crane which empties it either on to the heap or into wagons. The wagons to be loaded are grouped on the four central tracks and each travelling gantry crane moving very slowly can fill in succession two trains standing on the sidings. A fifth track arranged in the centre of the system ensures the possibility of independent shunting.

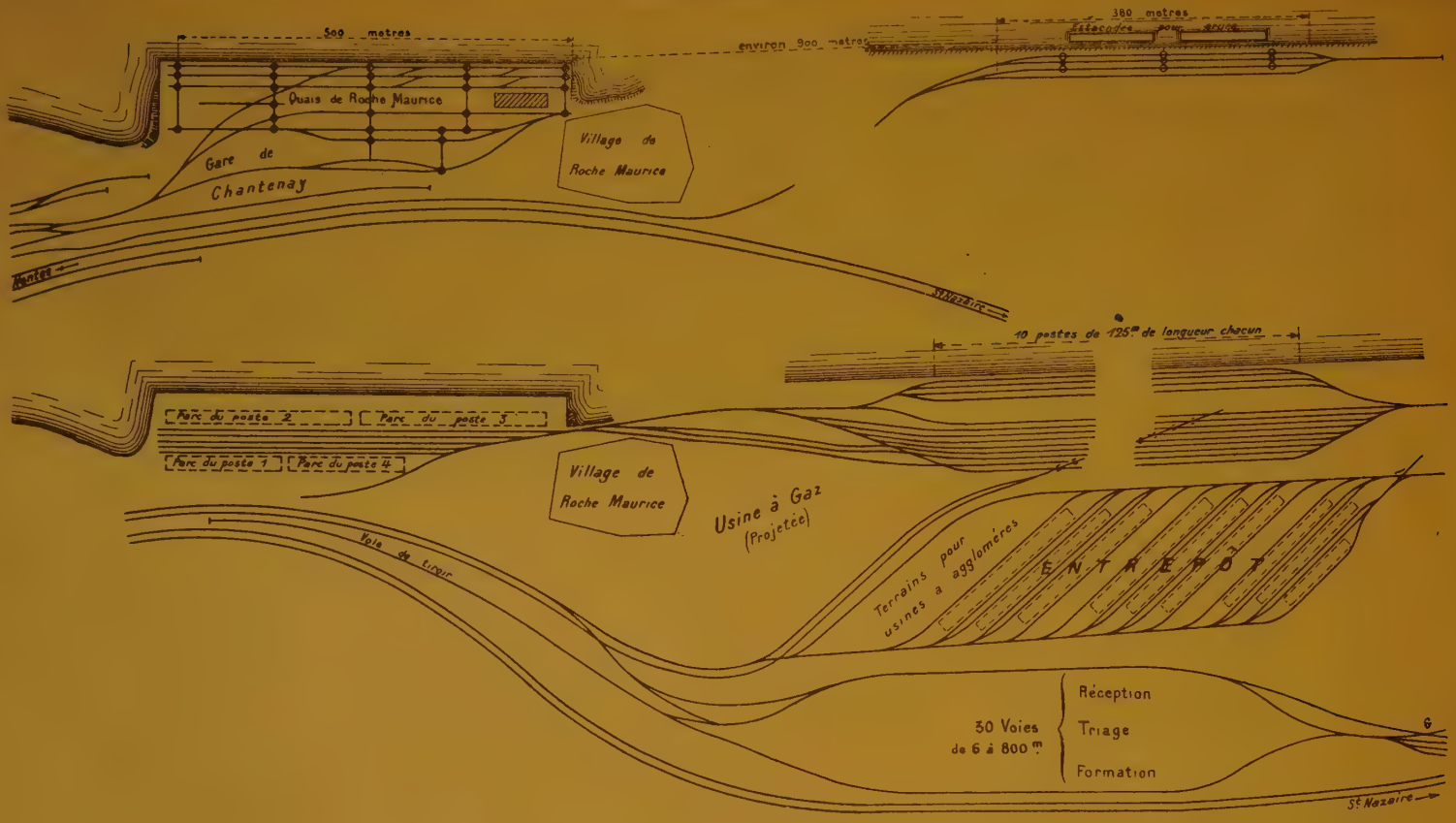
It is proposed to use automatic grabs, lifting from six to seven gross tons, with which the output per hour per berth will be from 250 to 300 tons of unscreened coal lifted from the suitably moored ships.

The row of 10 down-stream berths for various goods, will be completed by connections and lengthening of the separate berths which are now being installed.

The berths will be served by a large system of 13 tracks, 4 of which will run alongside the shore and be served by travelling elevated cranes, the other 9 tracks being allotted to the work of exchanging full and empty wagons and to that of carrying the traffic.

These 9 tracks will be connected to each other at Chantenay and to the new marshalling yard by a double track and a large spur cutting them through the centre. Between the 4 shore tracks and the 9 tracks at the back there will be a large platform, partially covered, on which the

Present arrangement.



Proposed arrangement.

Fig. 9. — Seaport of Roche-Maurice and splitting-up sidings at Chantenay (near Nantes).

Explanation of French terms : Environ = About. — Estacades pour grues = Staging for cranes. — Village de Roche-Maurice = Roche-Maurice Village. — Quais de Roche-Maurice = Roche-Maurice quays. — Gare de Chantenay = Chantenay yard. — 10 postes de 125m de longueur chacun = Ten berths each 410 feet long. — Parc du poste... = Yard allotted to berth... — Usine à gaz (projetée) = Proposed gas works. — Voie de tiroir = Draw-out siding. = Terrains pour usines à agglomérés = Ground for briquette-making works. — Entrepôt = Group of warehouses. — 30 voies de 6 à 800m = Group of sidings ; 30 tracks 1 970 to 2 625 feet long. — Réception = Arrival. — Triage = Splitting-up. — Formation = Marshalling.

cranes will place, and subsequently remove, such goods as must be sorted for reloading.

For the site of the marshalling sidings a flat piece of ground, not yet built upon, affords a satisfactory position for the main group of sidings which may comprise as many as 30 tracks from 600 to 800 m. (1 970 to 2 625 feet) in length. The group of sidings will communicate in the direction of Nantes by a turn-out loop, and in the direction of St. Nazaire by a group, G, of 5 tracks serving for the receiving and despatching of the trains.

Finally, between the tracks of the 10 berths and the new marshalling sidings a site is provided particularly suitable for the erection of large warehouses or factories which it is proposed to construct ultimately as shown on the sketch (fig. 9).

The port of Dunkirk (see fig. 12) served by the French Northern Railway comprises, outside the old port, 6 basins serving the jetties which are about 600 m. (1 970 feet) in length and 180 m. (590 feet) in width; these are arranged at an angle so that the tracks which serve them can be connected by points to a longitudinal group of continuous sidings. By means of this arrangement the wagons from jetties Nos. 3, 4, 5 and 6 have direct access to the junction lines, whereas the other 2 jetties deliver into an auxiliary system of sidings of 20 tracks, serving as a storage for trucks and being itself in communication with the group of junction lines by means of which it will be emptied as required.

Each jetty is equipped in general with a system of 3 tracks at the side of each quay and it is accepted that it will be able normally to serve berths of a length of 200 m. (656 feet) maximum, with 3 quay tracks each being able to receive, opposite to each of the berths, 15 to 20 wagons which are first placed near the shore end and are displaced successively during the loading operations.

A train may be removed as soon as the loading commences on the second train and it may be replaced by new empty rolling stock, or if necessary, the three adjacent sets of wagons may even be collected into a single train (on the quay-side itself, when the goods are intended for a single consignee) and made up into one train, in which case the brake wagons are suitably arranged in advance, and the train-locomotive, already coupled to the front van, backs down to haul the train away.

More generally the groups of wagons are withdrawn successively to the junction tracks.

It will be seen from the drawing, that the locomotive shed, which can obviously not be arranged without disadvantage on the sea-front, and which must on the other hand be placed where it is sheltered from the waves of sand raised by the wind, has been removed to a considerable distance from the shunting sidings of Coudekerque. In order that no difficulty may occur owing to this removal to a distance, when the main line locomotives have to return to the sheds after bringing their trains to the arrival siding, or when locomotives under steam have to be brought rapidly to the head of a train on the departure group of sidings, this locomotive shed is connected with the different groups by a system of locomotive tracks. These locomotive tracks are quite independent of the ordinary railway tracks and sidings, which are crossed at all points either above or below the level so that the locomotives can run at sight on their special tracks; these tracks form an integral part of the arrangement of the locomotive sheds and not of the general

traffic system; this amounts to saying that with the locomotive sheds placed practically at the head of each group of sidings, the time losses of the locomotives in existing systems, which are generally suffered in waiting for signals at the different nodal points, are abolished in this case (1).

On the same figure is shown the yard at the back at Noort Graacht, which is already partially constructed and which requires to be developed by the Chamber of Commerce particularly with a view to receiving imported locomotives requiring certain fitting operations before being despatched on the railway system.

Arrangement of open sheds, open stores public and private warehouses. — And their service. — It is almost always the case that a sufficient width is left, between the edge of the quay and the sheds, the various warehouses and the open storage spaces whether public or private, for placing direct-discharging tracks and waiting sidings (frequently of 3 tracks, sometimes of 4 tracks in all, of which 1 track, for handling the rolling stock, runs alongside the warehouses).

The warehouses are thus most usually arranged in the centre of the level ground spaces.

The greater number of the Railway Companies state that they effect the service of the warehouses and of the sheds by means of special tracks, one of which runs alongside that side of the sheds which is remote from the quayside. This method of operating has the advantage that it does not disturb the handling operation on the quayside tracks.

In ports of medium importance the service tracks for the handling of wagons in the port are also used for serving the warehouses.

To serve certain privately-owned sheds or storage spaces, which are generally constructed at some small distance from the quayside, special tracks are laid which actually form private sidings.

Handling machinery in use at seaports. — In seaports use is made almost everywhere of hand and steam cranes as well as of hydraulic or electric cranes which, according to the requirements, are either fixed, mobile or floating.

In some ports which are specially equipped to meet large movements of certain goods, such as grain, suction elevators are used when the goods are in bulk or endless belt conveyers for goods in sacks.

With powerful mechanical cranes use is often made of quick-acting grabs.

Powerful sheer-legs are used at some points for handling heavy and bulky goods.

At Marseilles, in the Russian basins served by the Russian Southern and Nicholas Railways and in the basins of the Norwegian State, use is made of high-duty elevators for grain.

The reply received from the Paris-

(1) This arrangement giving direct communication between the locomotive sheds and the heads of the different yards and of the splitting up and marshalling sidings, making the locomotives quite independent of the shunting operations in progress whether for departure or arrival, has moreover been adopted in a general manner for all the large shunting yards of the French Northern Railway that have been reconstructed since the war. In the present year (1921) it will be carried out at the large reconstructed shunting yards at Lille-la-Delivrance, Douai, Valenciennes, Hirson, Laon, Tergnier, whereas Dunkirk will only be completed with its new arrangements of the splitting up and marshalling sidings, and of the locomotive sheds in 1922.

Lyons-Mediterranean Company is worth quoting in its entirety :

The handling appliances used on the quays are operated either by steam, by hydraulic power or by electricity; they either occupy fixed positions on the quay or are capable of moving on rails or are floating on pontoons.

The use of machines worked by hand power is becoming more and more rare; there are however still a few hand-operated cranes for lifting heavy and unusual packages.

At Marseilles hydraulic cranes are used for the most part; six of these have been arranged on each of the longitudinal quays of the jetties and basins that are capable of receiving two large ships. The cranes are arranged on a staging placed a short distance from the edge of the quay; the cranes are mobile and can be moved when required by the hydraulic capstans arranged for handling the wagons. These capstans have two speeds; the lower speed is used for moving the crane and the higher speed for hauling the wagons.

The sheer-legs at Marseilles is arranged for three loads : 120 tons, 75 tons and 25 tons. The three lifts are effected by varying the water pressure.

In addition to these appliances there are suction elevators and conveyer belts carried at intervals on cast-iron rollers, so arranged as to make the grain collect towards the centre of the belts; the belts are flat and are only raised at intervals by the inclined rollers.

Similar belts are used for carrying grain in sacks.

On the Orleans Railway the mechanical installation of the ports on the Loire and on the Gironde are undergoing great development; this was increased during the war by the necessity for insuring the disembarkment of the American armies and their equipment. We have already mentioned the project for the improvement of the Roche-Maurice port on the Loire. We shall now deal with the installations made during the war at Bassens near Bordeaux on the Gironde and with the proposed extension (see fig. 10).

I. — The installations known as « Old Bassens » were constructed in 1916 and 1917 by engineers of the French State with the assistance of the Chamber of Commerce of Bordeaux and of the Orleans Railway Company.

They consist of 10 berths of an average length of 125 m. (410 feet) connected to the Paris-Bordeaux line by two junction lines : one, a double track in the direction of Paris (the left hand track of the junction is carried under the main line), the other a single track in the direction of Bordeaux.

The quayside tracks, properly so-called, consist of two groups : one of four tracks on the side of the Garonne, the other of two tracks at the back of a level space of a mean width of 40 m. (131 feet).

The tracks alongside the water are connected to each other, between the berths, by a spur with single points at the ends and double-slip points at each of the intermediate tracks.

The 10 berths are served by steam cranes of 14 m. (46 feet) reach. Their radius of action extends to two of the four tracks on the side of the water, the two other tracks serve as through sidings.

II. — The installations known as « New Bassens » were constructed in 1917 and 1918 by the American engineers with a view to the disembarkment of the American Army and of its supplies.

They consist of 10 berths each of a

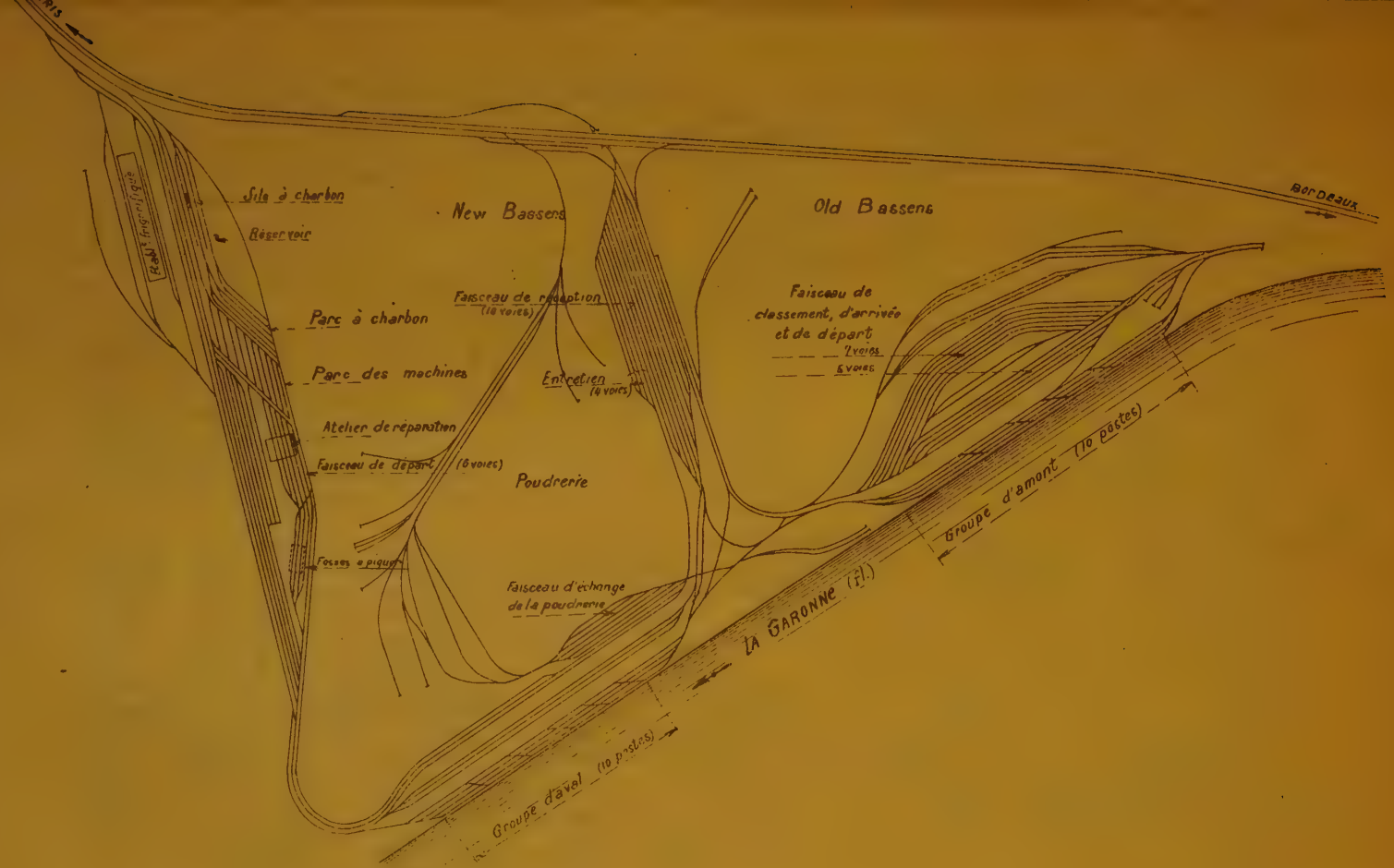


Fig. 10. — Bassens harbour (near Bordeaux).

Explanation of French terms : Etabl' frigorifique = Cold-storage depot. — Silo à charbon = Coal silo (storage hopper). - Réservoir = Water reservoir. — Parc à charbon = Coal storage. — Parc des machines = Locomotive sheds. — Atelier de réparation = Repair shop. — Faisceau de départ = Group of departure sidings. — Fosses à piquer = Locomotive pit. — Poudrerie = Powder factory. — Faisceau d'échange de la poudrerie = Exchange sidings from the powder factory. — Entretien (4 voies) = Maintenance (4 tracks). — Faisceau de réception (10 voies) = Group of arrival sidings (10 tracks). — Faisceau de classement, d'arrivée et de départ = Group of sindings for grouping wagons on arrival and for departure. — Voies = Tracks. — Groupe d'aval (10 postes) = Down-stream berths (10 berths). — Groupe d'amont (10 postes) = Up-stream berths (10 berths). — La Garonne (fl.) = The river Garonne.

mean length of 130 m. (427 feet), served by tracks forming a complete loop comprising, (apart from the common entrance track with that of the French installation); a receiving group of sidings perpendicular to the Garonne; service tracks for the charging bridges and for the open storage spaces; and a departure group of sidings connected to the main tracks at the special junction serving the great American yard at Izon. The effective length of the departure and arrival group of sidings is 720 m. (2 360 ft.).

The equipment in railway tracks of the charging bridges and store spaces comprises 4 water-side tracks spanned by travelling gantries each carrying a travelling crane. Behind the 4 water-side tracks there are in succession : one cart road, then a first line of sheds, then three railway tracks, then a second line of sheds then three more railway tracks.

The scheme for the extension consists in increasing the number of berths to 25 in all.

The berths will be served by two large groups of tracks connected separately to the Angoulême line and serving as a waiting siding as well as for the formation of trains whether full or empty : the first (down-stream) system of sidings, constructed on ground recently acquired by the Orleans Company, will deal with the 9 down-stream berths, at which the importation of mineral substances (coal, phosphates, pyrites) will take place. The second (up-stream) system of sidings, on the open ground, will use the junction lines already in service for the 16 berths at the centre of the up-stream portion.

The berths installed will be of three different types (fig. 11).

Type 1, of small capacity, is suitable for the importation and exportation of various merchandise, which does not admit of very rapid handling, and which is always unloaded on to the ground from the ship or from the wagon. This refers to such materials as are used for buildings and constructional work, agricultural machinery and mine-props. It is equipped with an electric gantry crane 50 m. (164 feet) between supports with a cantilever projection towards the river overhanging from 10 m. to 12 m. (33 to 39 feet). The bridge of the gantries carries a pivoting hand-crane with a reach of 12 m. to 15 m. (39 to 49 feet) and a capacity of from 4 to 5 tons. The wagons are brought to the open unloading space by tracks running alongside the outer boundary.

Type 2, of medium capacity, is suitable for cases in which a portion of the cargo is trans-shipped direct from the wagon to the ship or *vice versa.* It differs from the preceding one by the addition of three tracks near the shore, by arrangements for direct loading and by the increase in the equipement to two travelling gantry cranes one of 30 m. (98 feet) at the shore and an overhead travelling crane 20 m. (66 feet) span running on a raised track. The first covers work between the ships and the inner lines of rail and the open ground; the second covers the work between the open ground and the outer tracks.

In types 1 and 2 the arrangement of the open ground-space varies with the nature of the goods. If these require to be put under shelter, sheds may be put up, under the gantry cranes, either of one or two storeys and closed by sliding doors, which enable the goods deposited within to be handled by means of the cranes.

Type 3 of high output, is specially arranged for unloading, by means of automatic grabs, such finely divided minerals as coal, pyrites and phosphates. The

Type 1. — Embarkation and disembarkation of various goods always unloaded on to open ground or into sheds.

Type 2. — Embarkation and disembarkation of various goods direct from wagon to ship or *vice versa* or unloaded on to open ground or into sheds.

Type 3. — High-duty unloading of minerals by automatic grabs and conveyer belts including placing on the ground or loading into wagons from silos (storage hoppers).

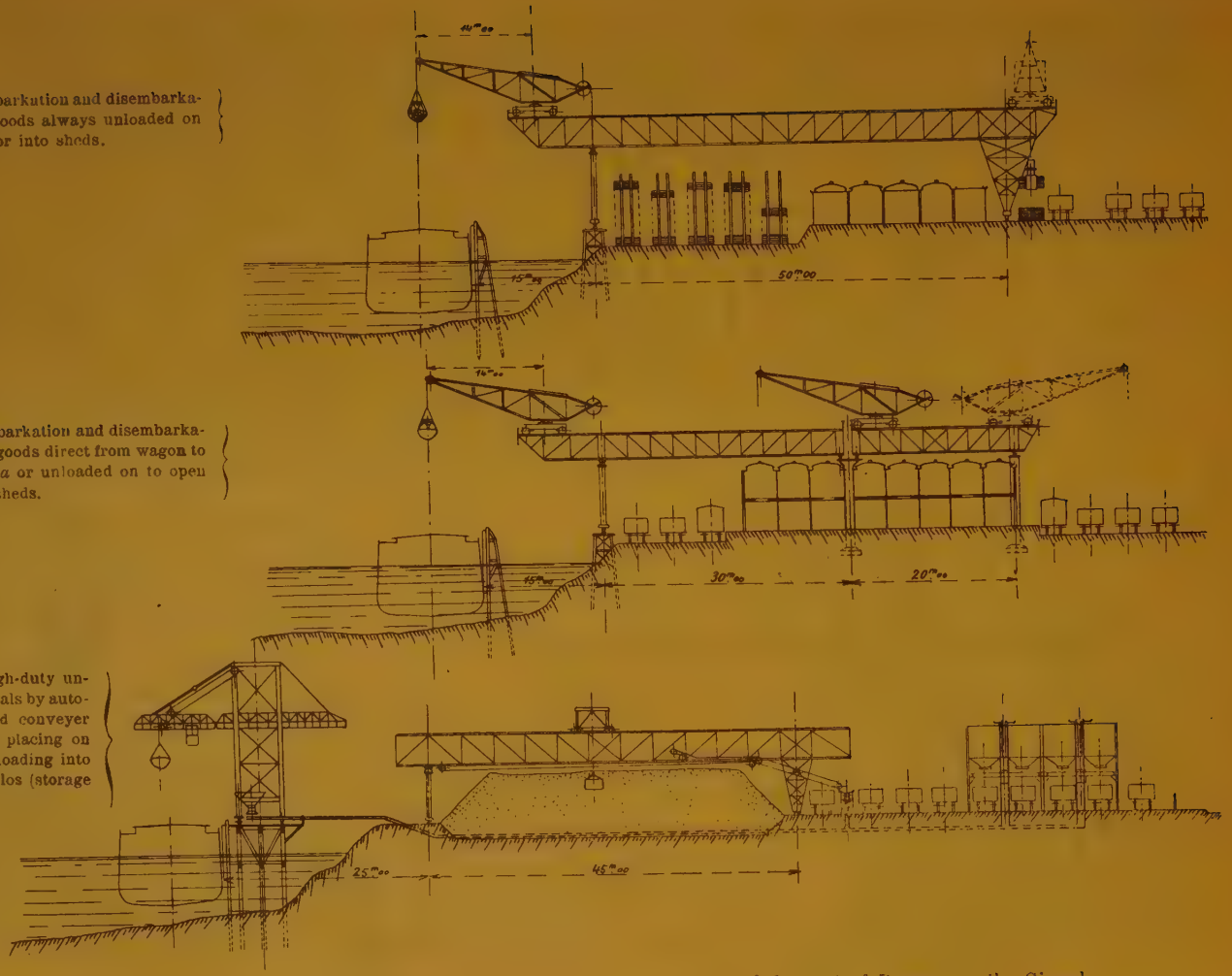


Fig. 11. — Various types of overhead cranes for the proposed arrangement of the port of Bassens on the Gironde.

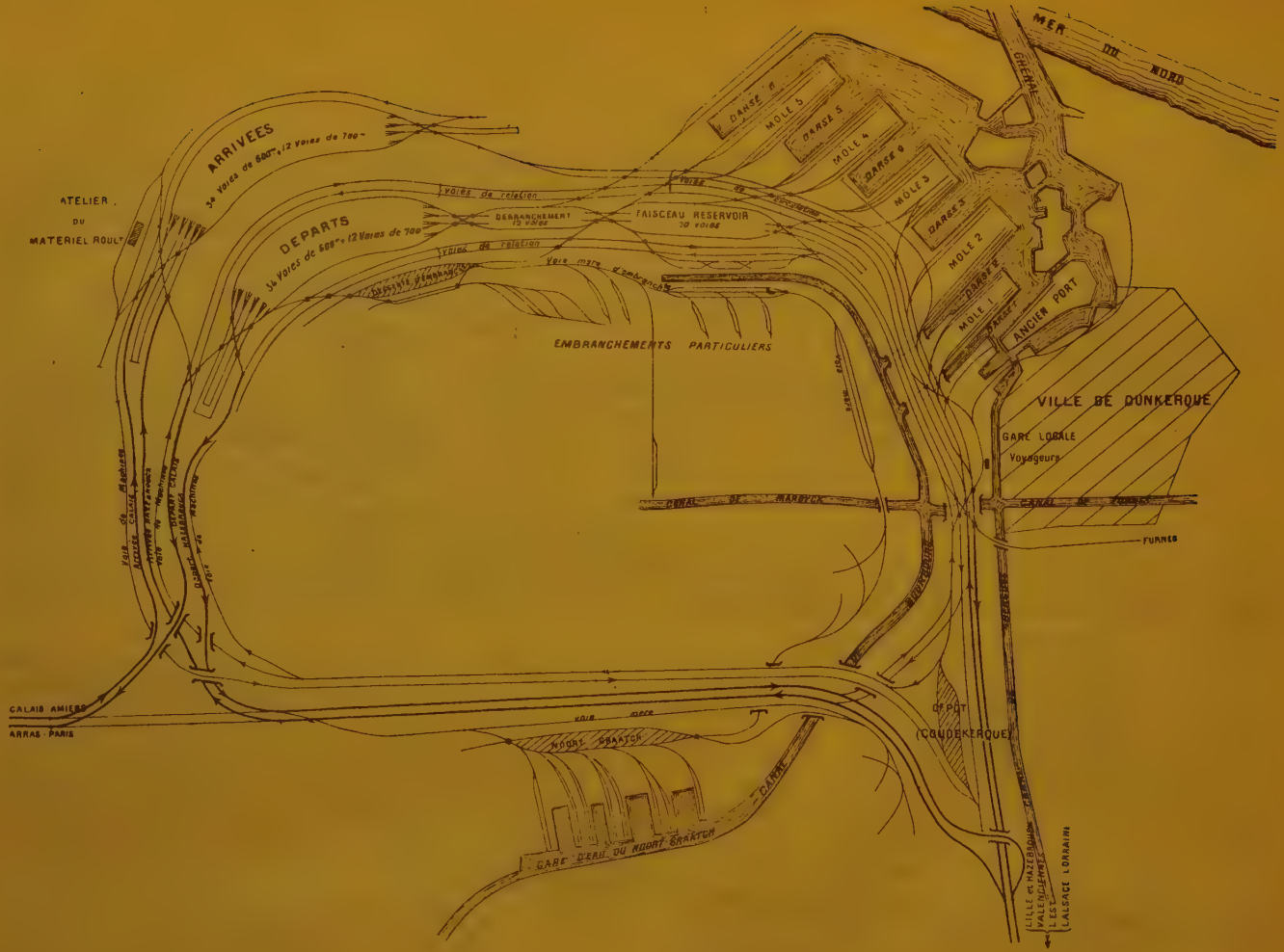


Fig. 12. — Port of Dunkirk.

Explanation of French terms : Atelier du matériel roul[t] = Repair shop for rolling stock. — Arrivées = Arrivals. — Départs = Departures. — Voies de... = tracks... metres long. — Voies de relation = Connecting tracks. — Voie mère = Main track. — Voie de machines = Locomotive track. — Départ Calais = Departure track for Calais. — Arrivée Calais = Arrival track from Calais. — Départ Hazebrouck = Departure track for Hazebrouck. — Desserte d'embranc[ts] = Service tracks for private sidings. — Voie mère d'embranch[t] = Main track to private sidings. — Débranchement 12 voies. = Group of sidings for branch tracks (12 tracks). — Faisceau réservoir 20 voies = Storage sidings for rolling stock (20 tracks). — Voies de circulation = Communication tracks. Darse = Bassin. — Môle = Jetty. — Ancien port = Old harbour. — Chenal = Channel. — Mer du Nord = North Sea. — Ville de Dunkerke = Dunkirk town. — Gare locale = Local station. — Voyageurs = Passengers. — Canal de Furnes = Furnes Canal. — Canal de Mardyck = Mardyck Canal. — Embranchements particuliers = Private sidings. — Canal de Bourbourg = Bourbourg Canal. — Dépôt (Coudekerque) = Coudekerque locomotive sheds. — Gare d'eau du Noort-Graatch = Noort Graacht canal docks. — Lille et Hazebrouck, Valenciennes, l'Est, l'Alsace-Lorraine = Lille and Hazebrouck, Valenciennes, French Eastern Railway, Alsace-Lorraine.

goods taken out of the ship are tipped on to a conveyer belt which takes them either to an open space or to a raised silo, from which they are loaded into wagons.

The relative advantages of the arrangement of long continuous quays and the arrangement of jetties with quays and parallel basins. — The Administrations which have answered our list of questions give the preference to one or to the other of these two systems basing their replies particularly on the local conditions and on the ultimate requirements.

The use of long continuous quays appears to be the most common; but certain administrations which use them exclusively, recognize that the arrangement of jetties would have greater advantages in practice in facilitating service by rail and in mooring the ships. Those ports which are situated on large rivers are almost compelled to adopt the system of long continuous quays (1).

The Orleans Company chiefly serves the large river ports on the Loire and on the Gironde. It has nothing but continuous quays and states that it is unable to form a comparison; but, apart from this case, the French railway companies are unanimous in finding that jetties and parallel basins are to be preferred to long, continuous quays, provided that the tracks running on to the sides of the jetties can all be connected to the splitting-up and marshalling sidings by means of points and not by turntables. At Marseilles (old harbour) there are jetties at right angles to the shore quay and access to the tracks on these jetties is only afforded by turntables; this makes the feeding of the wagons extremely slow. In the new proposed scheme, the jetties will be placed obliquely (in herring-bone arrangement) and the tracks will be made accessible by points. The Paris-Lyons-Mediterranean Railway also mentions Philippeville, Oran and Agha as ports equipped with parallel jetties; in the last port the jetties are arranged obliquely. The same arrangement of oblique jetties is, as we have just seen, adopted in the Freycinet docks in the port of Dunkirk.

The question arises as to what is the proper length to give to the jetties; those at Dunkirk are 600 m. (1 970 feet) in length.

It would appear that there is a tendency for the Harbour Boards of different countries to adopt jetties of greater length up to as much as 1 400 m. or 1 500 m. (4 600 or 4 920 feet). The French Northern Railway System, from its lengthy experience at the port of Dunkirk, considers that a length of 600 m. to 700 m. (1 970 to 2 300 feet) should not be exceeded, and that it is sufficient for berthing three large or four medium-sized ships. It must in fact be admitted that with the continuous movement of goods that we have been considering each berth should be immediately accessible, and consequently if the number of berths is extended over too great a length, the separate and parallel arrival tracks will cause a bottle-neck at the entrance to the jetty by taking up almost the whole width of the open ground; that is to say it would develop disadvantages similar to those of the river ports which can well be compared to excessive length.

The arrangement of parallel basins, with jetties 600 to 700 m. (1 970 to 2 300 feet) in length, allows complete and rapid service to be effected to all the quays by

(1) An arrangement has, however, been proposed with basins and jetties for the extension of the port of Rouen, on the right bank of the Seine, at the place known as « Les prairies Saint-Gervais ».

means of the simultaneous and almost continuous shunting operations which we have been considering; it is as unnecessary as it is undesirable to provide dead lengths on which goods and wagons would stand idle. Moreover, the arrangement enables complete service to be given, during the mid-day period of two hours when work is suspended, to all the yards where goods are handled (1).

CHAPTER IV.

Conclusions.

At the present time it is more than ever necessary to obtain the maximum output from the rolling stock by hastening its turnover and reducing the standing time for loading and unloading as much as possible.

This result depends on two conditions.

Firstly, it is necessary that the public should be educated, by commercial conditions carefully selected and rigorously applied, to carry out the handling operations in the shortest time possible.

We should make reference parenthetically to the new set of circumstances which have to be met by the French railway systems resulting from the slowing down of work, due to the application of the 8-hours day, and which have had so much influence on the output of the railway installations.

The immediate effect has been to paralyse the system of operations corresponding to the taking of delivery of the wagons by the public; the secondary effect has been to overload the large shunting yards with a greater number of wagons.

From this has resulted the necessity for finding remedies that have been sought chiefly in the extension of the local installations at the yards.

From the point of view of the unloading yards it must be remembered that before the war from 70 to 75 % of the wagons put into place in the yards before 10 in the morning were freed by the evening, by virtue of the clause requiring them to be freed in 6 hours : to this clause we have made reference in the first portion of this report. During the pre-war period the premium for quick clearing, although it was only from 5 to 10 fr. per wagon, according to the nature of the goods, was worth having and the public made an effort.

To-day, as a consequence of the unification of the tariffs over the whole of

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(1) With a view to this it would be desirable that the by-laws for the working of the ports should be conceived in a quite different manner to that formerly adopted; that is to say that instead of strangling the railways by restricting the time allotted to shunting operations, they should be given greater freedom for working continuously, and thereby enabled to give better satisfaction to everybody — to the shipowner whose boat is kept waiting for the minimum time, to the consignee, who is served in th shortest period, and even to the agents handling the goods who obtain a better output from their plant.

From this we come to the port completely closed by fencing which prevents idlers from walking about at their will and impeding the men who are at work; this is particularly important in ports at which goods that are trans-shipped direct from the ship to wagons represent more than 90 % of the traffic at the port. The local traffic can be excluded in such case, and it is less important because the local firms are directly connected to the railway system of the port by private sidings and supplied with trollies running on the railway metals instead of carts.

Even hough the port should not be closed by fencing, the operations, which are carried out in it with the concentration of installations now usual, forms an obstacle to the free movement of idlers who should be required to keep their own look out for danger, just as they are required to do in ordnary railway stations. The education of the public has a tendency moreover, to improve in this direction.

the French railway systems, this clause relating to freeing the wagons in 6 hours has disappeared. The penalties in case of delay in unloading, though much higher than the premium for clearing, are not sufficient to prevent these delays, because the ratio by which the penalties have been increased has been quite inadequate owing to the decline in the value of money.

It follows from this that the average period for which a wagon is standing when being unloaded at any particular yard is usually from two to two-and-a-half days (instead of less than 24 hours); so that in order to free 100 wagons per day at an unloading yard it is necessary that there should always be from 200 to 250 wagons in the yard and moreover it is necessary at the end of the day to undertake a much more complicated splitting-up of the groups of wagons that have been drawn from the sidings.

The same troubles are also found in the despatch where additional complications arise owing to the measures that it is necessary to take in order to give the despatchers the wagons that they require, both on account of the nature of the material and from the point of view of the railway system itself.

In fact, at each unloading yard, a group of sidings should be arranged having shunting facilities of a capacity of from one to one-and-a-half times that of the unloading yard itself; and this group of tracks should be closely connected to the tracks in the unloading yard or the group of unloading sidings in question.

The second condition to be fulfilled is that the yards should be so organized that the operations of putting wagons into place and removing them can be done at regular intervals and by complete groups of wagons, outside the hours at which the yards are open to the public.

If, owing to the nature of the traffic and the number of the consignees, frequent shunting operations are required the X arrangement of tracks, as spurs perpendicular or parallel to the service tracks, may be advantageously adopted provided that there is a sufficiently large unloading yard.

Turntables, on account of their small efficiency and of the amount of man-power they require, should be avoided in yards of more than average size.

In these yards it is preferable to adopt long continuous tracks between which convenient connexions by points should be provided. As far as possible the whole system of unloading tracks should be attached to the main tracks by points at both ends. Waiting sidings, of a number and length determined by the magnitude of the traffic, will allow the wagons to be put aside before and after they have been run on to the unloading sidings.

Heavy and bulky goods : stone, iron, coal, etc., should be handled oudside the ordinary goods yard in special yards arranged with machinery suitable for the work.

In working out the schemes for new yards, it may be taken that one square metre (10.75 square feet) of area covered is necessary for 25 to 30 tons of traffic per annum.

In important stations it is advisable to reserve separate warehouses for arrival and despatch as well as for fast and ordinary goods, provided that they are in direct communication, so that the wagons freed at the arrival warehouse have only to be moved a few metres before being reloaded.

With this object the warehouse with a

longitudinal central track cutting it into two long portions which are allotted, the one to arrivals, and the other to despatch, appears to offer advantages.

In the case in which there are several warehouses, the best arrangement appears to be that of placing them in line with each other. Everything, however, depends on circumstances and particularly on the ground that is available. Often the inadequacy of the site will compel recourse to warehouses with two or more storeys which should then be equipped with modern handling appliances with power in proportion to the traffic to be handled.

When high output is required an electric travelling crane with a pivoting arm should be installed. For the mechanical handling of packages of medium weight, carrying and tractor trucks, fitted if necessary with small cranes, should be used in conjunction with the other appliances.

Owing to their importance the tracks in seaports require to be made the subject of thorough study. It is necessary to facilitate the berthing of the ships and the service of the charging bridges by separating the whole of the quayside into separate basins by means of jetties constructed obliquely to the general direction of the shore, in such manner as to render easy the connexion of the sidings running on to the jetties with the general railway system by means of points.

In important ports having very heavy traffic it is necessary to provide, at the edge of the quays, several tracks for transshipment direct from the wagon to ship; close to these sidings there should be covered warehouses, large open storage depots, silos or storage hoppers for such goods as coal, minerals, etc. These installations should be provided with modern high-output equipment for handling goods and rolling stock.

It is the unanimous opinion that the tracks for the service and the handling of wagons in the ports should be connected to a large group of splitting-up sidings, but opinions differ as to the best situation for these large groups of splitting-up sidings. Some authorities think that they may, without disadvantage, be at a distance; they only require that groups of branch sidings, of splitting-up sidings, and of sidings for grouping and marshalling shall be provided of sufficient magnitude and arranged to give an adequate ,continuous and rapid stream of wagons leaving the port so arranged for the trains for their various destinations.

In our opinion the yards should preferably be as near to the seaport as possible, according to the ground left available by the installations for unloading and loading the ships; this is certainly a very great factor in determining the efficiency of the port itself.

[621 .135.2, 621 .135.3 & 621 .135.4

REPORT No. 2

(all countries, except those using the English language, Belgium, Denmark, Sweden and Norway)

ON THE QUESTION OF BOGIES [TRUCKS], AXLES AND SPRINGS OF LOCOMOTIVES (SUBJECT VI FOR DISCUSSION AT THE NINTH CONGRESS OF THE INTERNATIONAL RAILWAY ASSOCIATION), (1)

By Mr. BOCHET,

GENERAL INSPECTOR OF MINES, SECRETARY OF THE TECHNICAL COMMITTEE FOR THE WORKING OF RAILWAYS AT THE MINISTRY OF PUBLIC WORKS OF FRANCE.

Figs. 1 to 18, pp. 197 to 238.

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(1) This question runs as follows : « Best arrangement of the bogies, axles and springs of locomotives, especially of locomotives for high speeds, with long wheelbases, so as to facilitate running round curves and to ensure the proper stability of the engines. »

The present question includes, with certain additions, the subjects treated in question VIII at the Congress of 1889 and in question XIII at the Congress of 1900; the first was specially devoted to the means for facilitating the running of rolling stock in curves, and the second had for special object increased stability in running by the use of very flexible springs and compensating beams or equalisers.

It seems interesting to recall, at the beginning of this report, the conclusions which, as far as the present question is concerned, were come to by the preceding Congresses (1) :

1889.. — *Locomotive engines.* — « The many various methods used on locomotive engines for facilitating running in curves were discussed at the meeting. It recognised that, according to the cases, successful use had been made of : longitudinal or transversal play in the axles, under control or not, thinning or even the suppression of the tyre flanges of the intermediate axles, articulation of coupling rods, special couplings, a great amount of taper on the front wheels, etc.

It drew attention to the use of oblique buffers, particularly for engines in which the front axle has much play.

It pointed out the different arrangements allowing the axles to converge, such as radial boxes, pony trucks and, especially for high speeds, front bogies with a wheel base considerably longer than the width of the gauge between rails.

It also considered that the use of compensating beams to insure the proper distribution of the load on the wheels is good practice.

Finally, it considered that engines with one or two motive trucks are suitable solutions in certain exceptional cases.

1900. — Compensating levers are of advantage, more particularly on lines with varying gradients or frequent curves, as they tend to diminish the irregularity of load on the wheels when curves are entered and changes of gradients encountered. On fairly level lines, with permanent way maintained in good condition, experience shows that locomotives which are not fitted with compensating levers are capable of doing excellent work.

Springs of great range appear to have but a limited field of application in locomotive practice.

* * *

For the preparation of the present report, information was asked for in 1913, and then in 1920, from the principal railway administrations of the following countries :

Argentine Republic, Spain, France and Algeria, Italy, Luxemburg, Holland and its Colonies, Roumania, Switzerland and Uruguay.

More or less complete replies were received from the following systems :

Argentine Republic :

State Railways;
Central Argentine Railway.

Spain :

Andalous Railway;
Northern of Spain Railway.

(1) See *Bulletin du Congrès des chemins de fer*, number of March 1890, p. 382, and *Bulletin of the Railway Congress*, number of December 1901, p. 2609, also *Proceedings of the third session* (Paris, 1889), vol. 2, p. VIII-133, and of the *sixth session* (Paris, 1900), vol. 3, p. XIII-161.

France and Algeria :

Alsace & Lorraine Railway;
Est Railway;
Etat Railway;
Midi Railway;
Nord Railway;
Paris-Lyons-Mediterranean Railway;
Orleans Railway;
Algerian State Railway.

Italy :

State Railway.

Luxemburg :

Prince-Henri Railway.

Swiss :

Federal Railway.

Uruguay :

Central Uruguay Railway.

Holland :

Netherlands State Railway (1);
Dutch Railway (1);

Dutch Indes :

State Railway (1).

These replies contain at least a partial description of the methods of suspension or a few particulars of a somewhat large number of kinds of locomotives, the types of which will be classified in the course of this report, according to the number of axles of the various categories to which they belong. From amongst the notations in use for this purpose, we will choose that which appears to us the clearest and simplest, representing each type by a number of three figures, the first of which is equal to the number of front carrying axles, the second to that of the coupled axles and the last to that of the back carrying axles.

This number will be preceded whenever it is found useful (especially in numerical tables, and in marginal references for research purposes) by a distinguishing letter for the system to which the type of engine referred to belongs. This abbreviation of the titles of the various companies will be made according to the list below :

A = Algerian State Railway;
C = Central Argentine Railway;
D = Andalous Railway;
E = French Etat Railway;
F = Swiss Federal Railway;
G = Argentine State Railway;
H = Prince-Henri Railway;
I = Italian State Railway;
L = Paris-Lyons-Mediterranean Railway;
M = French Midi Railway;
N = French Nord Railway;
O = Paris à Orléans Railway;
P = Northern of Spain Railway;
R = Alsace and Lorraine Railway;
S = French Est Railway;
U = Central Uruguay Railway.

* * *

The replies received do not generally mention the arrangements containing innovations on the lines pointed out in this respect by previous Congresses. The generalisation of the use of bogies and pony trucks and the progressive elimination of the contrivances they took the place of seem to be the chief features of the actual situation.

As regards other questions, such as that concerning compensating beams, the position then taken up by the various companies appears to be generally maintained.

The question arose as to whether the

(1) These replies, with a number of drawings sent without due notice, came too late to be made use of in the present work.

present investigation should include all methods of traction, especially those relating to electric locomotives. A few systems having supplied particulars of the latter in which the general conditions of balancing are somewhat different from engines with reciprocating motions, it appeared to us more expedient to limit ourselves to the examination of those only which relate to steam locomotives. We have also eliminated articulated locomotives, the use of which is still somewhat exceptional in those countries with which this report is dealing.

These general indications having been given, we may now proceed with the examination of the different contrivances and the various arrangements which we have to consider successively.

I. — Bogies.

The bogie, the progressive generalisation of which has been pointed out at various Congresses and exhibitions during the last quarter of a century, has now become a necessary accessory for all locomotives having to haul fast trains. Its advantages are unanimously acknowledged, and there is no longer any company which does not use it for this class of work.

The methods however employed in its construction are still very diverse and, in what follows, the various points of view which appear to be the most interesting will be examined.

a) *Method of carrying the main framing on the bogie.* — Two schools are found in presence in this respect, the Alsatian and the American.

The first allows the framing to rest on two side supports, the distance between which is about the same as that between the rails; it believes there is an advantage in widening the seating of the body of the locomotive and making the suspension springs of the bogie participate in the lateral straightening action, and by that means diminishing the effect of the rolling motion.

The second makes use of one support only placed in the centre of the bogie, in order to find by that means the equalisation of the load between the wheels and the constancy of its distribution in spite of the local difference of level of one or the other rail; moreover, it considers that it obtains a greater suppleness in entering curves and so avoid excess loads on the wheels that may fatigue the road, or a lightening of the load which might bring about derailing.

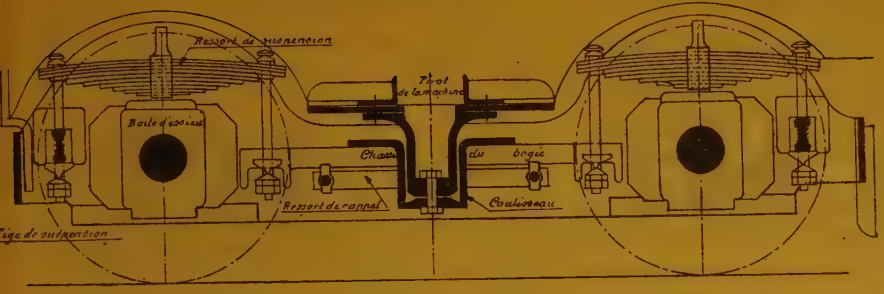
Bogies of the first kind are only or nearly only used up to the present on the French Companies of the Est, Midi, Nord, Alegerian (State), as well as on the railways of the Northern of Spain and Andalous. S. 230 M. 230 M. 231 N. div. A. 230 P. div. D. 230 O. 231

The bearings are nearly all arranged through the intermediary of a shoe, the flat bottom face of which slides on the machined surface of horizontal supports, the top face being hollowed like a spherical cup so as to receive an embossed seating connected with the main framing.

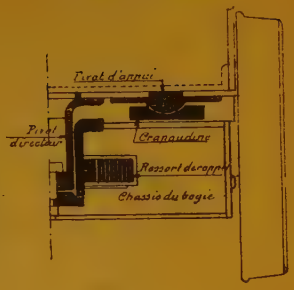
The connection in plan between the engine and the bogie is obtained by means of a guiding vertical pivot, which forms part of the main framing and penetrates the central hole of a sliding plate fixed in the middle portion of the bogie and capable of a certain relative amount of lateral play on transversal slides arranged for this purpose (fig. 1).

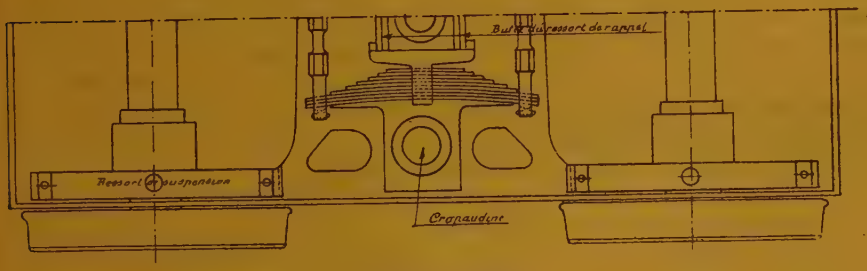
In the American bogie, the pivot constitutes the point of support of the load; this support is made through a circular,

Longitudinal section.



Half-cross section.





Half-view in plan.

Fig. 1. — Bogie used by the French Est Company.

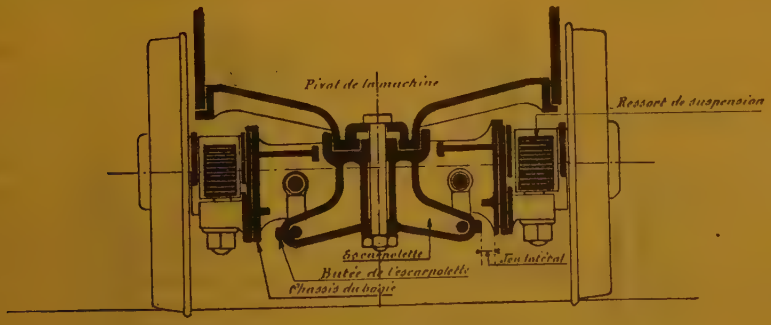


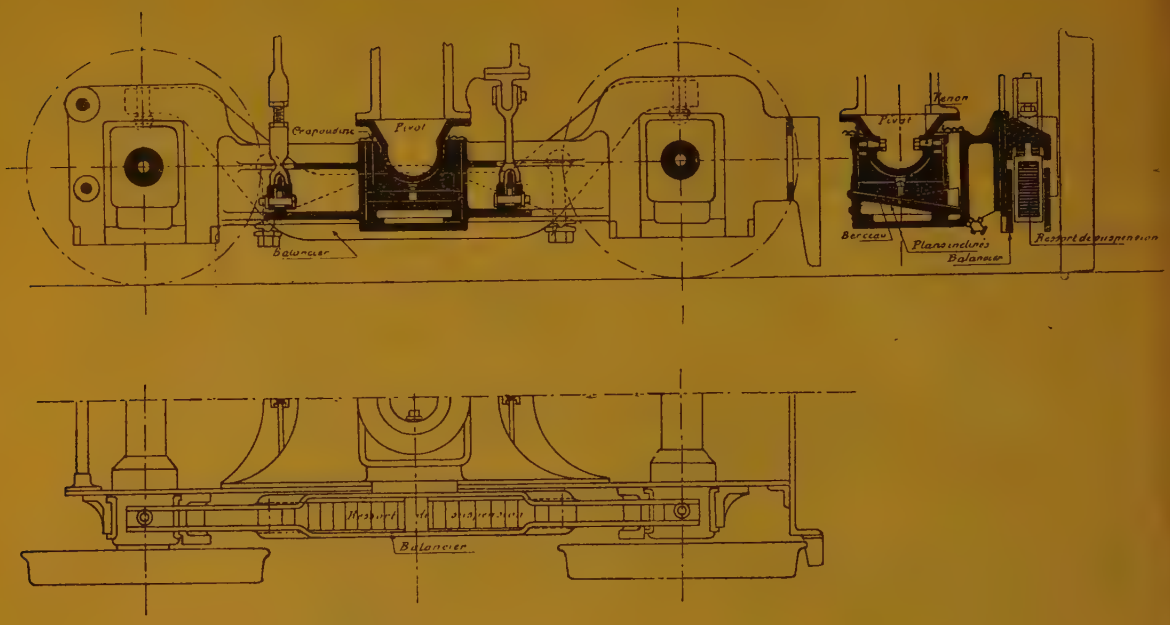
Fig. 2. — Bogie used by the French Etat Company. — Cross section.

flat or rather annular surface, the outside diameter of which is about 30 cm. (12 inches) and resting on a bolster hung by means of four links to the bogie frame and susceptible of a swinging motion in a transversal direction (fig. 2).

The French Etat, the Italian State, the Central Argentine and Uruguay systems E. 230 E. 231

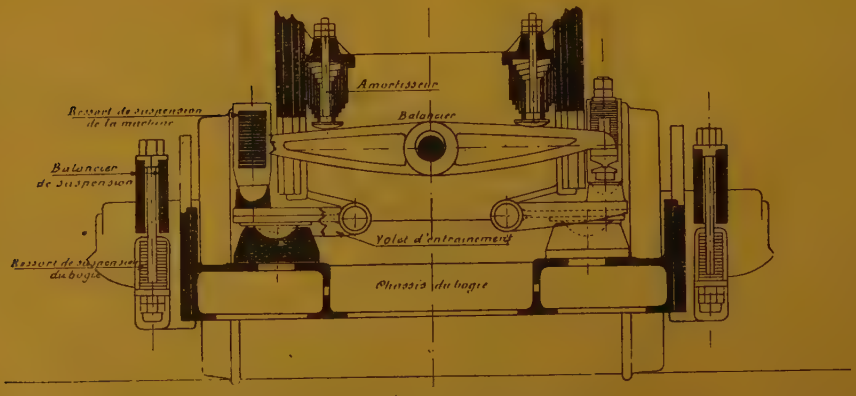
Longitudinal section.

Half-cross section



Half-view in plan.

Fig. 3. — Bogie used by the Paris-Lyons-Mediterranean Company.



Cross section behind the distributing equaliser.

Fig. 4. — Back bogie of engines 3.1101 of the French Nord Company.

I. 231 C. 240 C. 231 U. 222 O. 221 and 230 F. 230 use exclusively this type of bogie, which is also met with concurrently with the Alsatian type of bogie on the Orleans system and on the Swiss Federal Railways.

It should be noted that the necessity of obtaining by means of the pivot support a solidarity in the direction of the transversal movements between the main framing and the bogie tends to cause a certain amount of cylindrical clamping between the base of the pivot and the bogie centre plate forming the top of the swinging bolster, but this clamping does not generally extend far enough on account of the slight play it has, to affect the character of the central support which is the principle of this method. According to the sketches sent of the Swiss Federal rolling stock, this does not appear to act in the same way, as the boxing up is rather too deep and tight to form a real solidarity to bring in reality the carrying of the main framing on to the suspension pins of the links thus causing an intermediate arrangement between that of a central support and the side supports properly so called.

F. 230

The bogie of the Paris-Lyons-Mediterranean (fig. 3), used only by this Company for many years, is also made with one support, which is even more exactly central than that of the American bogie; it is in fact accomplished by means of a spherical pivot and centre plate, so that in the oscillatory motion of the bogie, the point of transmission of the force due to gravity is always vertical with the centre of the sphere instead of undergoing a displacement, the amplitude of which may, in the American bogie, reach the diameter of the circular supporting plane.

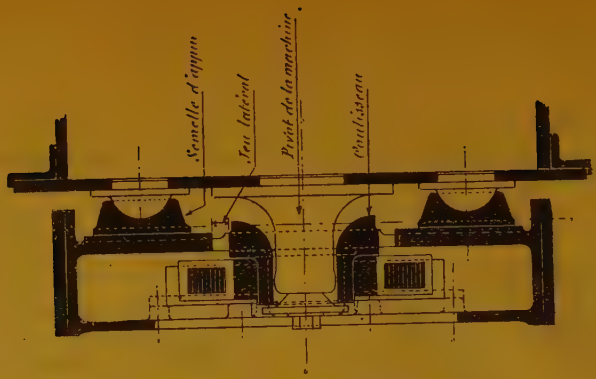
L. 230 L. 231 L. 240

It is interesting to point out, that by the side of these well known systems, a special arrangement (fig.4) adopted by the French Nord for the back bogies fitted to a series, containing however only a few powerful high speed engines belonging to type 232. It is fitted with flat lateral supports, but the main framing rests on them through the intermediary of laminated springs connected by a transversal compensating beam at one of their extremities, which is practically identical with the conditions appertaining to a central support, moreover, the oscillations of the compensating beam are reduced by spiral springs acting vertically on each of its arms. Finally, in order to avoid that the forces due to transversal displacement are directly transmitted to the spring buckles, an intermediate fitting is interposed, oscillating round a longitudinal pin fixed to the framing of the locomotive and absorbing the forces in question (see fig. 4). The general arrangement is somewhat complex, but on the other hand no special difficulty arises in its upkeep and it is said to work to the entire satisfaction of the Company; the endeavour to avoid inconvenience in working to the engine staff from bumping and shaking appears to have been thus obtained.

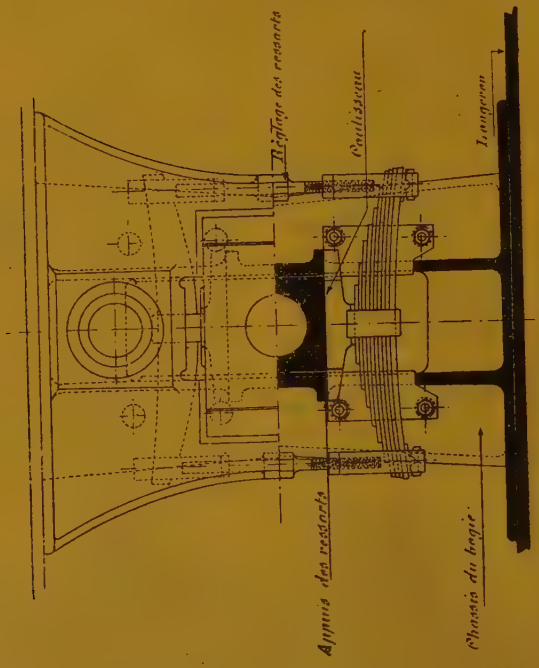
N. 232

b) *Centreing arrangement.* — Bogies with side supports are brought back to their mean position by means of springs acting on the sliding centre plate. For this purpose either plate springs or spiral springs are used, the choice of which seems to be only determined by consideration of the space that may be available.

In quite a general way, the plate springs are fixed on each side of the centre plate, the ends of the two springs being connected one to the other by means of rods fitted with screwed couplings, the whole (fig. 5) forming a rectangular framework in which the middle of the springs press against bear-



Section through the centre of the bogie.



View in plan of the arrangement.

Fig. 5. — Bogie with side bearings and plate spring centreing arrangement.

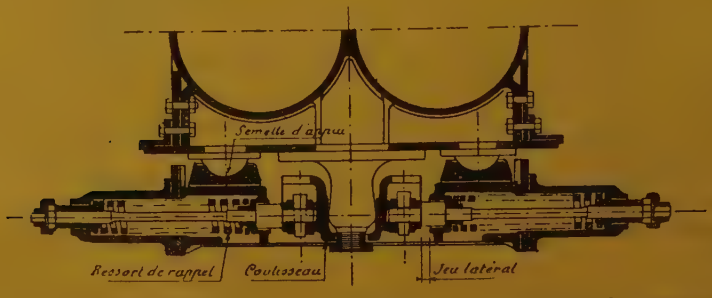


Fig. 6. — Bogie with side bearings and centreing arrangement by means of helical springs. — Cross section through centre of bogie.

ings fixed on the inside part and are forced outwardly by the action of the centre plate.

Helical springs are generally double and fixed tandem fashion on each side of the centre plate (fig. 6); the latter in its displacement carries with it rods which are attached to it by cotters and which pass through the centre of the springs and terminate with a head on the outside, so that when one of the springs is directly compressed by the action of the centre plate, the other is compressed the same amount through the intermediary of the corresponding rod. Other arrangements with helical springs are too exceptional to be worth while describing. Spiral springs also are only used under similar conditions in a very small number of cases.

To all these springs an initial compression is powerful enough to keep the bogie in its mean position against the influence of jerks or small disturbing forces. In facing these outside forces, the bogie intervenes like a rigid axle to resist the tendency of vibration; its mobility enters into action to overcome the larger perturbations or to facilitate its running in curves.

In the American bogie, transversal centreing is accomplished by the action of gravity, any displacement of the swing seating or bolster from its position of equilibrium causing a rising of the centre plate due to its suspension by links. This rising however is at the commencement very small, so that the initial centreing effort is nil.

The partisans of this system greatly appreciate the ease arising from this property from the point of view of entering a curve; they compare the results obtained in this respect to those obtained by the use of parabolic joining up in the plan of the line; on the other hand, its adversaries find that when running on the straight there is too much freedom of motion which they consider excessive and prejudicial on account of the continual vibration, which is annoying to the engine staff and harmful to the working parts of the locomotive.

Most of those systems which use this type of bogie have judged it necessary to remedy these inconveniences, either by adding a centreing spring, like the Italian State, or by adopting the system of links called « triangles » which are carried at one of their extremities by two parallel pins and do not begin to oscillate round one of them, keeping however parallel between themselves, until the force tending to cause the displacement reaches the magnitude corresponding to an inclination given by the simple links of the American system properly so called (1). I. 231

The locomotives described by the Uruguay and Central Argentine Companies, as well as the swinging bolster bogies of the Swiss Federal Railways, are fitted with triangular links. The Orleans Company has been led by experience to use them in the place of simple links which were first fitted to certain classes of their engines; more than 100 of their locomotives are now supplied with them and the alteration has given all the satisfactory results which were expected. U. 222 C. 231 C. 240 F. 230 O. 221 and 230

On the other hand, the French Etat, which made a trial of the same modification in 1912 on 15 of their 230 class engines have not found a very marked improvement, and have continued to use for the rest of their stock the simple E. 230

(1) It should be pointed out that the simple links inclined in the form of an isosceles trapeze only have an action from the point of view of initial centreing which is absolutely insignificant.

links, only shortening them in their newest engines so as to increase the intensity of the centreing force more rapidly.

L. div. Only the Paris-Lyons-Mediterranean obtains the transversal centreing effort for its bogies by means of inclined planes and even superposes an angular centreing arrangement which no other company thinks necessary to consider. To obtain this, the spherical pivot and bogie centre plate are, by means of tenons fixed in mortices which are lengthened only in the vertical direction, made to work together from the point of view of rotation round the vertical axis; in addition the bottom of the bogie centre plate rests on a cradle with spiral surfaces, having for axis the axis of the pivot, on which the bogie centre plate rises each time that under the action of the pivot it turns round this centre line; it is the cradle itself which bears on the inclined transversal centreing planes mentioned above. The whole arrangements appears at first sight somewhat complicated, but enclosed in an oil bath it works very regularly and almost without attention, and the company which has used it for many years on all its bogies is very satisfied with it.

b') *Amount of play allowed and magnitude of the centreing force.* — The transversal displacements of the bogie are limited by stops fixed on each side of the central pivot. These stops are generally non-elastic, the Paris-Lyons-Mediterranean Company fits them with small spiral springs so as to make the buffering elastic.

The amplitude of the angular displacement is sometimes allowed to be unchecked, in most cases however it is limited by other stops generally fixed at the back end of the bogie.

If we call :

D the distance of central stops to the plan through the middle;

d the distance of the furthest stops to the same plan;

l half the length of the bogie,

the maximum angular displacement is equal to :

$$\text{arc tan.} \frac{D + d}{l}$$

The magnitude of the centreing force and the law of its variation is differently expressed according to the systems adopted :

With plate springs arranged as described above, the displacement x of the bogie centre plate is distributed in halves between the two springs which transmit by degrees the same force F. If the individual flexibility of the springs is n millimetres per ton, and the initial compression is equal to a, we get in consequence:

$$F = a + \frac{x}{2n}$$

With spiral springs, between which on the contrary the force is distributed while they are both compressed x millimetres, the formula becomes

$$F = a + \frac{2x}{n}$$

With the system of inclined planes, the centreing force is constant and equal to the load on the bogie multiplied by the coefficient of inclination of the plane.

In either case, springs or inclined planes, friction must be taken into account, proportional to the load on the bogie and according to a coefficient which depends on the condition of the lubrication of the the bearing surfaces; it is in order to

decrease this coefficient that sometimes the rubbing surfaces are arranged at the bottom of a trough in which an oil bath is maintained. The friction under consideration acts so as to increase the resistance to side play, which without it would be equal to F, and to decrease by the same amount the centreing force properly so called.

With swinging bolster supports, the influence of friction is reduced to that of the pins in their bearings, which is practically negligible. The centreing force due to gravity varies according to a sinusoidale law which, in the case of vertical links of length h, is expressed by the formula

$$F = P \times \frac{x}{\sqrt{h^2 - x^2}}$$

in which P represents the fraction of the weight of the locomotive bearing on the swinging seating or bolster.

The same formula applies in the case of triangular links, on the condition of making h equal to the distance from one of the top bearing pin centres to the bottom one, and by increasing x to half the distance between the centres of the top pins.

Finally, the case of inclined links does not lend itself to establishing a formula which is at the same time simple and exact; it is only necessary to remember that the initial contreing force is nil and that initial derivation of its value in terms of the function of the displacement x is $\frac{P}{h}$, as in the case of vertical links, h representing the vertical projection of the links when in their position of equilibrium.

Table I gives, for those engines for which sufficient details have been supplied, the values for maximum displacements and of the centreing force, with particulars with which it may be interesting to compare these values.

c) *Suspension.* — Many companies use for the suspension of bogies on the axles the simple arrangement of independent springs for each wheel generally in the form of plate springs fixed above the axle boxes and connected to the bogie framing by means of hangers screwed in the ordinary way (1); on one system only (Uruguay) spiral springs are used, but no reason is given for this preference. The Swiss Federal Railways have been induced, in order to correct the insufficiency of flexibility of plate springs on a certain class of bogie, to superimpose spiral springs; this is a chance solution on which it does not appear necessary to dwell, though the results obtained are declared to be satisfactory. U. 222

Other systems consider it advisable to order or accept from their builders a connection by means of a compensating beam between the two wheels on the same side, and we find, especially in the case of subsequent taking over (French Etat, old 231), the common compensating beam joining the two springs to be connected together. In the American bogie of the Swiss Federal Railways the arrangement is similar, but the other way about, the axle boxes directly supporting rigid beams joined together by means of a plate spring which forms the compensating beam. E. 231 F. 230

The most usual form of connection

(1) In the bogies of the N. 232 of which a particular feature is described below in the paragraph « Method of support » these springs do not bear directly on the boxes, but are connected to a given bar, the extremities of wich rest on the said boxes, this does not affect their character of independence (fig 7). N. 232

TABLE I.

ENGINES.	Weel base		Distance		Maximum displacement		Weight			Centreing force without taking friction into account		Remarks.
	rigid, in metres	total, in metres.	from bogie centre to first coupled axle, in metres.	between bogie axles, in metres.	lateral, in millimetres.	angular.	on the bogie, in kilogrammes.	of the bogie, in kilogrammes.	total on the rail, in kilogrammes.	initial.	maximum.	
						Centreing by means of plate springs.						
S. 230	4.95	8.89	2.89	2.10	55	3°	19 610	5 230	24 840	1.785	5 715	Class 3.100
S. 230	4.10	8 15	3.075	1.95	55	3°	15 790	5 300	21 090	1.785	5.715	Class 3.800
M. 230	4.70	9.10	3.25	2.30	50	1° 30′	17 400	4 900	22 300	4.000	6.717	
M. 231	4.10	10.70	2.85	2.30	50	1° 50′	17 400	4 900	22 300	4.000	6.717	
N. 231	4.30	10.35	3.00	2.30	65	3° 45′	18 750	5 250	24 000	3.800	7.050	
F. 230	4.35	8.65	3.215	2.17	65	...	19 500	5 500	25 000	1.250	...	Class 600
						Centreing by means of spiral springs.						
O. 231	4.10	10.70	2.85	2.30	45	1° 45′	17 900	5 300	23 200	4.500	9.000	
A. 230	3.50	7.10	2.575	2.05	40	2°	10 825	4 175	15 000	2.800	...	
N. 221	2.15	8.50	2.90	2.10	45	2°	13 750	5 500	19 250	5.000	9.500	
N. 230	4.30	8.55	3.20	2.10	45	3° 52′	14 500	5 500	20 000	5.000	9.500	
D. 230	3.90	8.60	2.70	2.00	30	1° 30′	11 200	4 800	16 000	1.300	2.900	
P. 230	4.00	7.50	2.50	2.00	30	2° 30′	...	...	...	1.500	4.700	
P. 231	3.80	10.05	2.75	2.20	45	1° 45′	...	...	17 200	2.150	4.300	
P. 240	5.10	8 95	2.75	2.20	55	2°	...	...	17 700	2.150	4.540	
P. 242	5.10	12.75	2.75	2.20	45	1° 45′	...	...	18 000	2.150	4.300	
						Centreing by means of inclined planes.						
L. 230	4.60	8.535	2.935	2.00	34	No	15 740	5 800	21 540	2.360	2.360	
L. 231	4.20	11.23	2.85	2.30	34	imi-	14 760	5 800	20 560	3.250	3.250	
L. 240	5 50	9.25	2.70	2.10	34	tation.	10 380	5 000	15 380	1.560	1.560	
						Ceintreing by means of swinging links.						
E. 230	4.81	8.70	2.79	2.20	60	1° 30′	17 690	4 910	22 600	0	7.150	
E. 231	3.95	10.75	2.75	2.10	60	1° 30′	15 965	5 035	21 000	0	6.450	old.
E. 231	4.10	10.90	2.85	2.30	60	1° 30′	18 490	4 950	23 400	0	9.620	new.
O. 230	3.90	7.70	2.75	2 10	45	...	14 300	4 700	19 000	2.740	6.000	
U. 222	2.15	9.15	2.90	1.90	100	...	p.	...	14 880	0.125 p.	0 564 p.	
F. 230	4.15	8.35	3.20	2.00	44	...	14 000	4 400	18 400	2.800	6.000	Class 700
I. 231	4.30	10.05	2.70	2.10	40	...	15 700	4 300	20 000	300 (1)	3.520	(1) additio-
C. 231	4.05	9.45	2.66	2.00	45	...	14 700	4 700	19 400	2.750	5.830	nal spring.
C. 240	4.90	8 67	2.80	2.00	70	...	14 900	4 700	19 600	2.800	8.000	

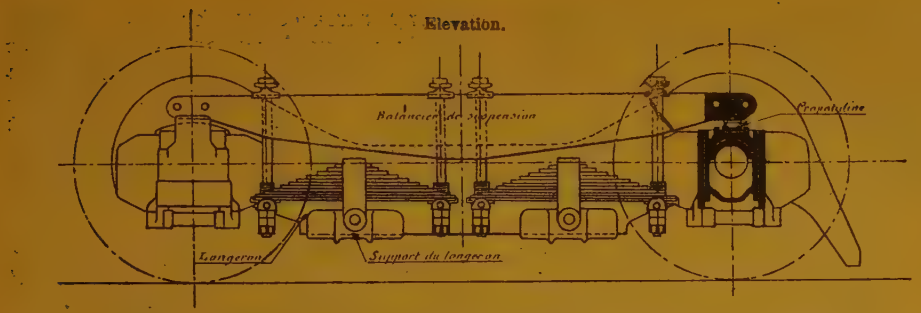


Fig. 7. — French Nord bogie of engines 3.1101. — Suspension arrangement.

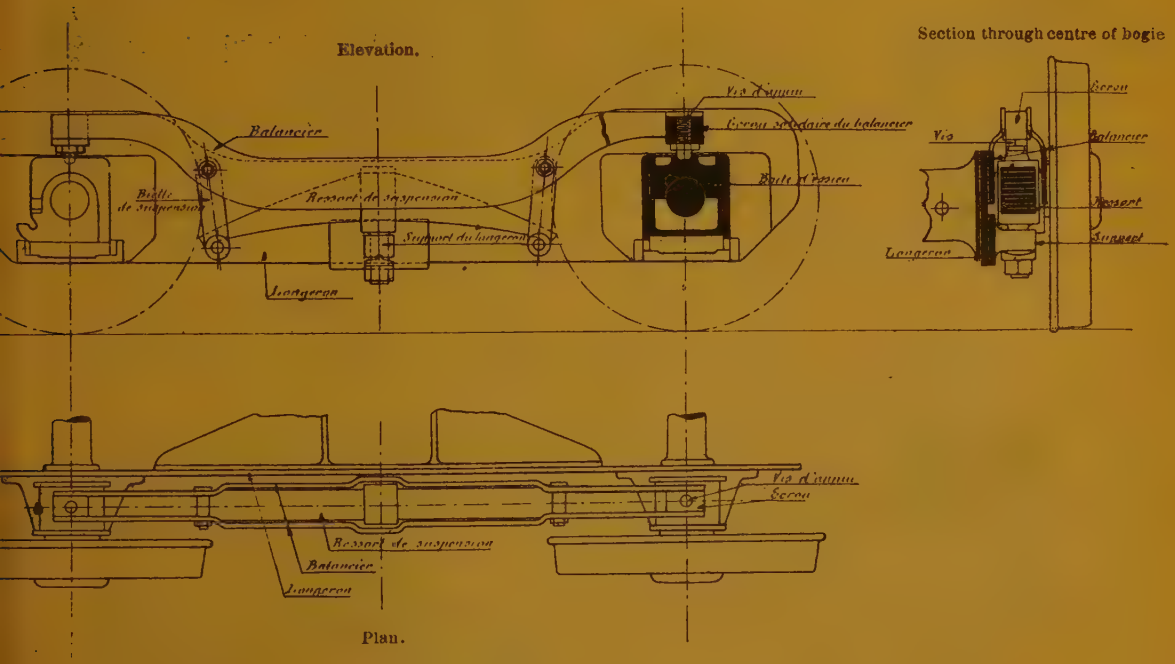


Fig. 8. — Bogie used by the French State Railways. — Suspension arrangement.

. 230 found, particularly on the French Etat
. 231 and Paris-Lyons-Mediterranean Railways,
. div. as well as on certain engines of the Or-
. 221 leans, is that of the American type in
. 230 which one longitudinal plate spring is fastened by its two extremities at two points of a rigid compensating beam made longer than the spring and bearing directly on the axle boxes (fig. 8).

It should be noticed that, the longitudinal connection by means of the compensating beam, combined with the central spherical bearing, leaves the bogie in an indifferent state of equilibrium with

respect to the galloping motion. This is
L. div. an inconvenience which the Paris-Lyons-Mediterranean system has corrected by the addition at the back of the pivot of a vertical tie rod which connects the main framing to that of the bogie, and of which the length, sufficient not to interfere with the horizontal displacements of the bogie, is adjustable by means of a screw. A second similar tie rod, which is shorter but with sufficient play, is fixed in front for the same purpose for measures of safety.

d) *Lubrication.* — The following extracts from the information supplied appear to be of the most general utility :

French Etat. — The oil is distributed by means of « spider leg » grooves cut radially in the surface of the bogie centre plate; it is fed by means of a pipe which delivers the oil in front of the pivot in the old engines and by two pipes feeding back and front in the most recent types.

French Nord. — The pivots properly so called are not lubricated; the centre plates which carry the pivot are lubricated by means of small oblique channels which end on their bearing surfaces. For the lubrication of the bearing surfaces of the body of the engine, the spherical bearings are fitted with oil grooves and the bogie centre plates with a small vertical channel ending at their bottom part, which is also supplied with two rectangular oil grooves.

French Est. — The lubrication of the sliding surface of the spherical bearings of the main framing of the engine on the bogie, as well as that of the bogie centre pivot, is insured by means of valve lubricators fixed on the outside of the frame of the engine and fitted with supply pipes which conduct the oil to the required points.

French Midi. — The lubrication of the rubbing surfaces of the bogie centre plate is accomplished by means of pipes leading from two oil cups fitted with trimmings. There is no lubricating arrangement for the pivot and spherical bearings; they are satisfied with giving them a coat of thick grease from time to time.

Paris-Orleans. — Have no particular arrangements; lubrication is effected by directly oiling the parts requiring it or by means of oil cups and oil holes.

Paris-Lyons-Mediterranean. — The combination of the pivot and the inclined planes work in an oil bath; between the pivot and the frame a cover joint of leather is fixed, thus preventing dust entering; a cock at the bottom part of the basin allows the oil to be emptied.

Italian State. — Lubrication of the bogie centre plate is accomplished by means of an ordinary oil box with wick trimmings.

Andalous. — The distribution of oil is effected by means of grooves and oil holes into which lead from fixed oil boxes pipes.

Central Argentine. — Lubrication by oil is supplied from a syphon lubricator.

Other systems. — No details.

II. — Bissel-bogies.

The Zara bissel-bogie is used on the Swiss Federal Railways and on the French Orleans and Paris-Lyons-Mediterranean systems.

It may be explained here that this is an arrangement of a bissel, the oscillating pivot of which, instead of being fixed on the main framing, swivels on a sheath carrying the boxes of the first coupled axle and allowing the latter a slight transversal motion which it can make in relation to the main framing; to allow for this

displacement, the amplitude of which is limited by stops, the coupling rod is provided with spherical joints.

The locomotive is supported on the axle boxes of the two front axles which form the bissel-bogie through the inter-

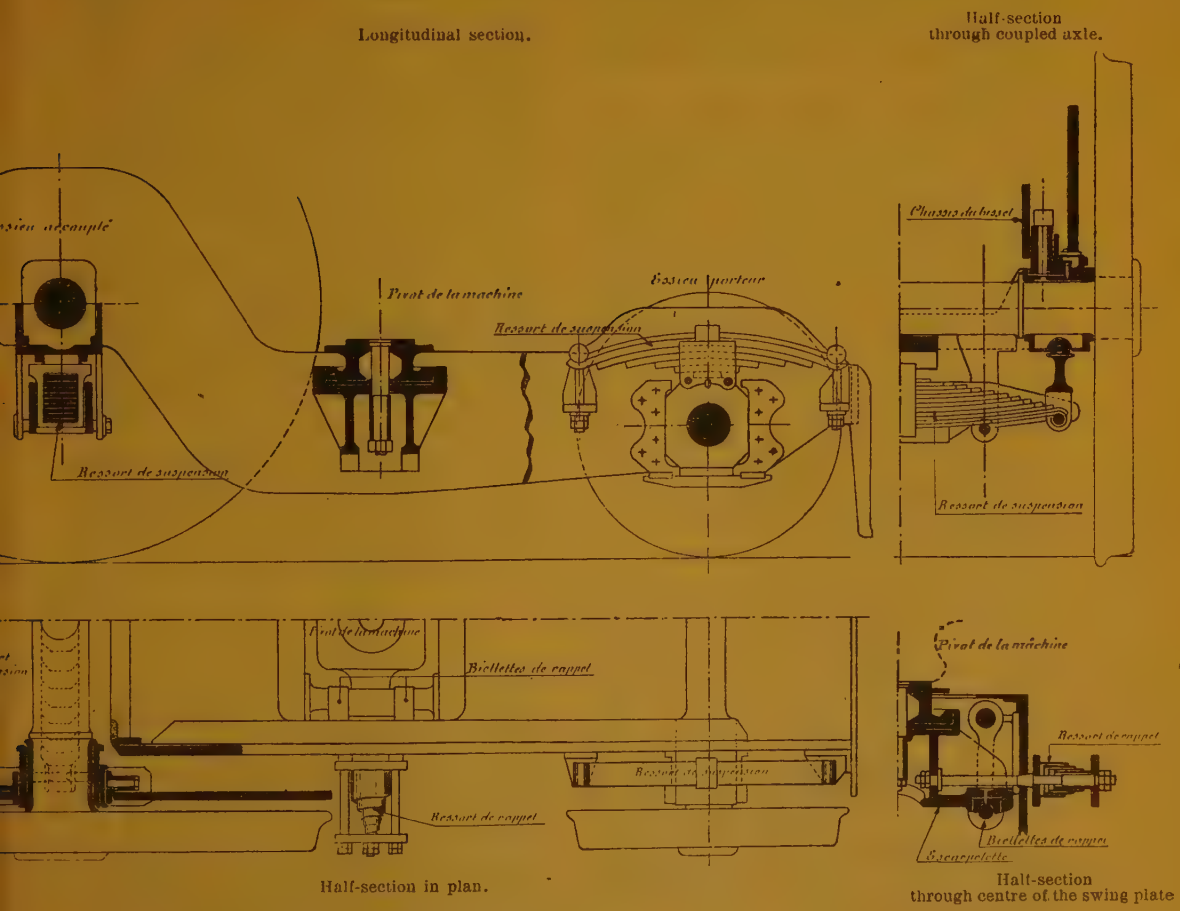


Fig. 9. — Bissel-bogie used by the Italian State Railways.

mediary of plate springs joined together by means of longitudinal compensating beams. The transversal and angular displacements of the tail of the bissel is controlled by a pivot fixed to the main framing; a framework of plate springs is interposed between the slider and the bissel.

The Federal Railways made no comment relative to the working of this arrangement, but it may be noticed that while it is fitted to the first numbers of each of the classes of engines types 131 and 150, the following numbers of both classes are not supplied with it. F. 131 F. 150

The Paris-Lyons-Mediterranean system L. 140

which fitted it to its 140 type locomotives, has no intention of extending its use and has even transformed it back to the simple bissel on some of them; they attribute to it unequal wear of the tyres, fractures of the tail and other inconveniences in working.

O. 141 The Orleans system recognises in it certain advantages; it has it says a guiding facility in curves much superior to that of the ordinary bissel, from which results a decrease in the wear of the flanges of the coupled wheels and the reaction of the engine on the road so much so that higher speeds may be allowed on lines containing curves of 200 and 150 m. (10 and 7 1/2 chains) radius; but, for the service on other lines it seems to be uselessly complicated because of its delicate adjustment and difficulties of lubrication; consequently it is only applied on new stock for locomotives destined for mountain railways.

On the other hand, the bissel-bogie is very much in favour on the Italian State Railways, who have fitted it to the greater part of the engines described belonging
I. div. to the 130, 131 and 140 classes. This railway system considers that it has about the same qualifications for safety in running and steering round curves as the bogie with two carrying axles, and it finds an advantage which is very important for a hilly road, in the increase of adhesive weight with an equal total weight of the engine.

The type of bissel-bogie of the Italian State (see fig. 9) is however very different to the Zara type. It comprises a central flat swinging bearing suspended by four vertical links; with an increase of lateral centreing force by means of a spiral spring as mentioned above in respect to bogies of the same system. It is supported a little behind the centre on a real bogie frame which rests in front on the boxes of the carrying axle through the medium of independent plate springs and at the back on the middle of a transversely fixed plate spring, the extremities of which are supported by hangers under the boxes of the coupled axle, thus forming an equaliser between the two wheels and this axle. The latter moves in conjunction with the back of the framing, the corresponding coupling rod being fitted with spherical joints.

The same type of bissel bogie was . 140
fitted in 1908 to 30 engines, type 140, built for the old Western system and now belonging to the French Etat, which was so satisfied with their working, as to order during the course of the last few years a new series of 270.

The principal numerical details relating to bissel bogies, which are not in use on the other railways consulted, are given in table II, which is similar to the previous one in the chapter on bogies.

III. — Bissels or pony trucks.

Few locomotives are now built the total weight of which is used for adhesion, and the advantages of flexibility in its thrust on the rail renders the arrangement well known as the *bissel or pony truck* to be adopted nearly always for the front carrying axle, which is fixed to a small special framing with a triangular tail, the back summit of which swivels on a pivot attached solidly to the main framing, whenever the speed in view does not warrant the choice of a bogie.

The carrying axle can thus move transversely under the main framing in oscillating round the vertical axis of the pivot. It is desirable that in this motion, the axle may remain normal to the centre line of the road, and this result is obtained, whatever the radius of the curve may

Table II.

ENGINES.	Rigid wheel base. not including.	Rigid wheel base. including.	Distance between the two axles of the bissel-bogie, in metres.	Maximum displacement. from the pivot, in millimetres.	Maximum displacement. from the coupled axle, in millimetres.	Maximum displacement. angular.	Weight. on the bissel-bogie, in kilogrammes.	Weight. of the bissel-bogie, in kilogrammes.	Weight. total on the rails, in tons.	Centreing force on the pivot not including friction. initial, in kilogrammes.	Centreing force on the pivot not including friction. maximum, in kilogrammes.	Arm of leverage (*a*) of the centreing force, in metres.	*Remarks.*
	the axle of the bissel-bogie, in metres.												
F. . . . 130 / 131	2.05	3.90	2 50	40	20	2° 30′	21 500	5 000	26.5	2 200	...	1.245	
F. 150	4.70	6.45	2.35	47.5	20	2° (1)	21 200	4 600	25.8	1 250	...	1.175	(1) The displacement of the carrying axle is limited to 70 m/m.
O. 141	3.35	5.00	2.35	42	17	2° 30′	26 650	4 650	31.3	1 000	4 300	1.165	
L. 140	4.25	6.13	2.50	40	5	2° 15′	19 950	5 150	25.1	2 033	4 230	1.125	
I. 131	1.95	3.95	2.50	30	20	2° 30′	19 100	6 900	26.0	300	3 000	1.120	
I. 130	2.25	4.10	2.65	20	20	2°	18 800	6 300	25.1	300	2 625	1.120	Class 625.
I. 130	2.25	4.20	2.55	20	10	1° 30′	18 400	6 700	25.1	300	2 600	1.120	— 640.
I. 130	2.20	3.90	2.30	37	10	2° 30′	17 000	7 300	24.3	300	4 330	1.120	— 880.
I. 140	3.54	5.59	2.60	40	20	3°	18 900	8 600	27.5	300	3 725	1.120	— 745.
I. 140	3.00	4.70	2.60	20	20	2°	1 800	6 000	24.0	300	2 500	1.120	— 740.

(*a*) In relation to the back articulation, situated to the right or in the neighbourhood of the coupled axle.

be, on the condition that between the length x of the tail, the distance b from the carrying axle to the first coupled axle and the rigid wheels base a, the following relation exists

$$x = b \times \frac{a + b}{a + 2b}$$

In the engines described, the difference between the real length of the tail and the theoretical length given by the formula is often below 5 %; it is however considerably greater on some lines. These no doubt do not attach much importance to the question, whilst others, like the French Est, see, in obtaining a correct solution, an advantage on account of a noticeable decrease in the wear of the tyre flanges.

Another point which appears to pre-

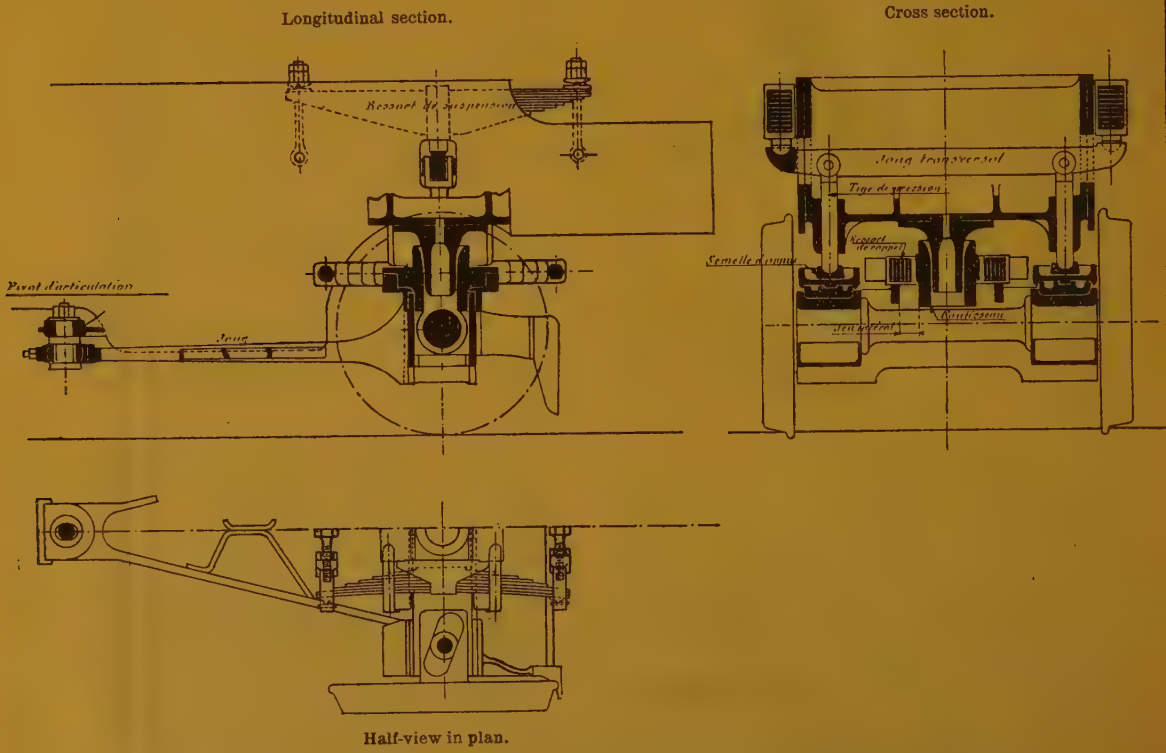


Fig. 10. — Bissel with lateral bearings and centreing arrangement by means of plate springs.

occupy only a small number of companies relates to the method of hauling the bissel; these companies take care that the latter is always pulled and not pushed; to obtain this, they give to the back swivelling pivot a fair amount of longitudinal play so that the hauling is always made by the pivot controlling the transversal motion which is fixed in front. When this pivot does not exist, as in those cases with a central bearing, the same tractive principle from the front is

worked by means of horizontal rods converging like sides of a trapezium which connect the front of the bissel to the front of the main framing. This arrangement
S.O.P. is found chiefly on certain Alsace-Lorraine, Est, Orleans and Northern of Spain engines.

In the method of supporting the locomotive on the bissel, we find, as in the case with bogies, the solution in the central support as well as in side supports; the same arguments, which sometimes have to give way to other considerations, are advanced in defence of one or other system.

The bissels of the Midi and most of those of the French Etat, which are similar to one another (fig. 10) have lateral bearings fitted with shoes which slide through means of a horizontal flat surface on the tops of the boxes holding in
S. div. spherical cups the spring columns; these springs however, for reasons of crowding, do not bear directly on these columns, but a little to the outside on to the extremities of a cross bar which is itself carried by the columns.

The Midi complains that this arrangement causes a rather rapid wear of the columns in their guides and risks of seizing; the Est has not experienced any inconvenience of this kind in practice.

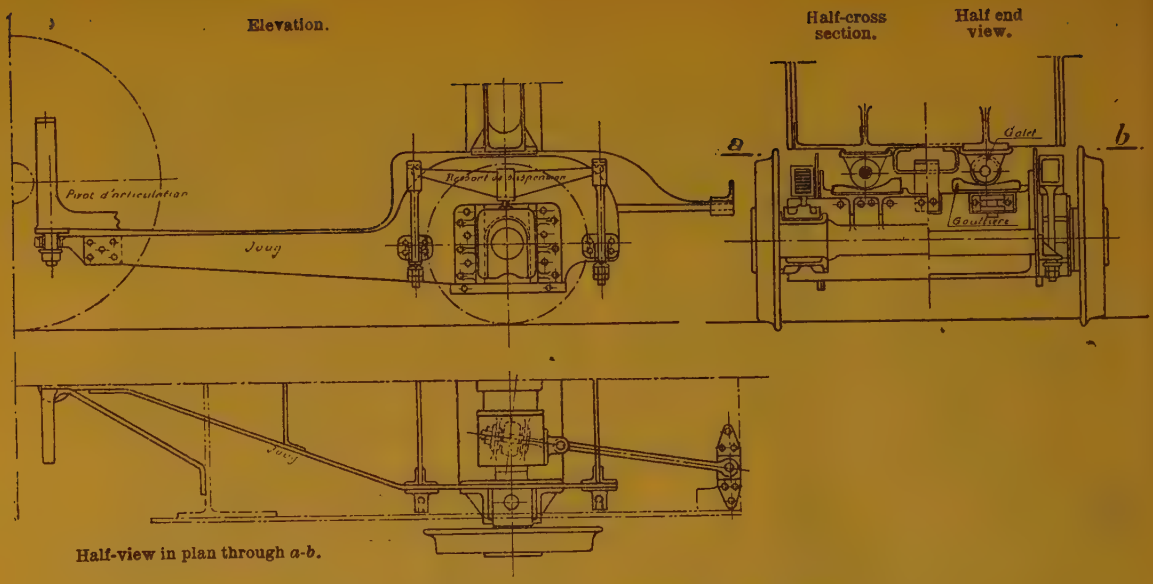
The transversal centreing is made in a line with the axle by means of a framework of plate springs, similar to those described above when referring to bogies; the Est has been exceptionally forced, on account of transforming some old engines
S. 130 of type 130, to make use of spiral springs for this form of centreing arrangement.

Spiral springs are again found for centreing purposes on the bissels of locomo-
L. 140 tives, type 140, of the Paris-Lyons-Mediterranean. These bissels, which have originated from the transformation mentioned above of Zara bissel-bogies, shew the same method of support of the main framing as those of the Est and the Midi, with this difference, that the springs are connected by means of longitudinal equalisers with those of the first coupled axle, and also that they bear directly on the tops of the columns without overhang.

The centreing spring took its bearing on the main framing by means of two buffers, the friction of which on the side of the frames caused a too great solidarity between the main framing and the bissel in the direction of the vertical displacements. This is at least the reason to which it was thought that a certain number of derailments of this class of engine might be attributed, in fact these derailments ceased to occur when the above mentioned buffers were changed for bearing rollers. Before however they had made certain of the facts, the Paris-Lyons-Mediterranean had ordered a new class of locomotive with bissels of another type, which will be described further on.

The Swiss Federal Railways have also adopted for their most recent engines, type 150, a bissel supported laterally by F. 150
columns resting on the top of the axle boxes through the medium of a cupped shoe, but this bearing takes place on flat surfaces that are inclined transversely, so that the centreing is due to the action of gravity. To increase the centreing force, the sliding surfaces having only an inclination of 12 %, and in order to render it progressive, spiral springs have been added laterally.

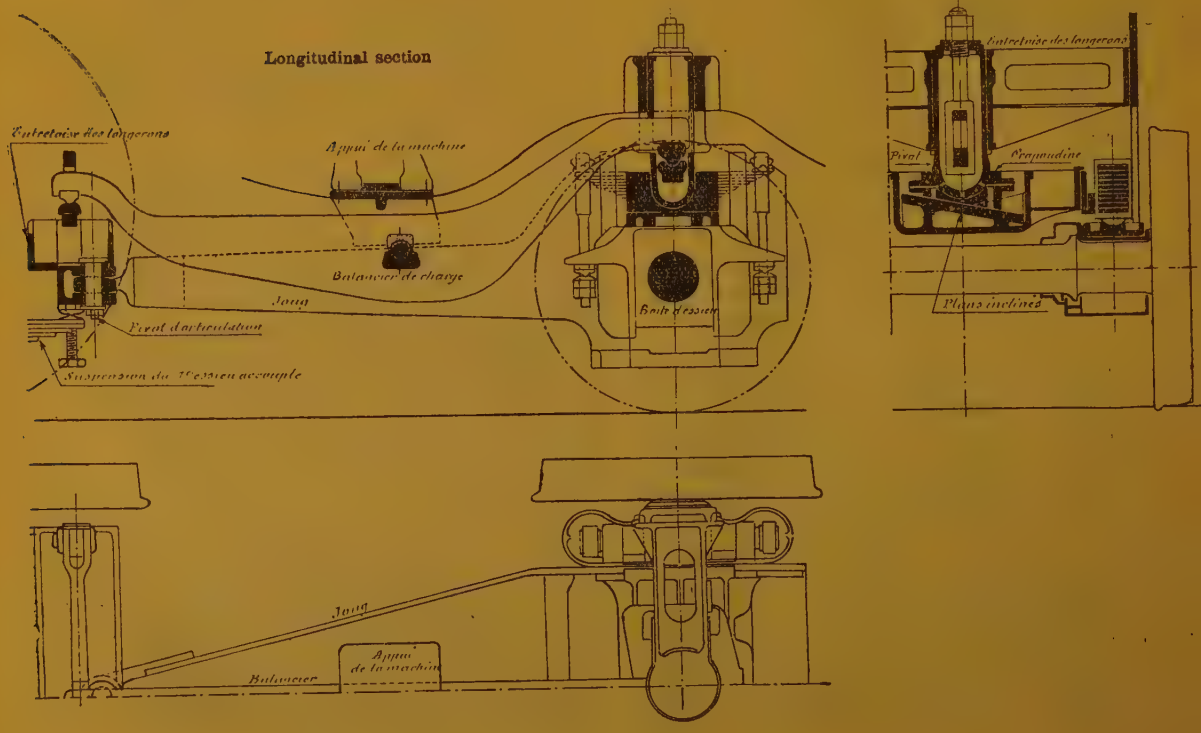
Finally we find again side supports with gravity centreing in the bissels of the 140 class engines of the Northern of P. 140
Spain, but the arrangement is somewhat peculiar (fig. 11). Firstly, the distance of the bearing points to the central plan of the engine is only 0.325 m. (12 13/16



Half-view in plan through *a-b*.

Fig. 11. — Bogie used by the Northern of Spain Company.

Half-section through axle.



Half-view in plan,

Fig. 12. — Bissel used by the Paris-Lyons-Méditerranean Company.

inches), afterwards these are formed by rollers carried on the main framing and moving on fittings, fixed to the bissel, of which the top face is cut in the form of a gutter forming two converging inclined planes and a projecting stop arrangement at the inside extremity. No remarks or information as to the working of this system has been supplied by the company.

Amongst the bissels with central support, of which the types described are somewhat numerous, though several only differ from each other in secondary arrangements or even details, many are fitted with a suspension connection with the first coupled axle; the bearing of the main framing is then made on a longitudinal equaliser which is fixed along the centre line of the engine, the back extremity bearing on a transversal equaliser joining the front ends of the springs of the coupled axle, or else their suspension links, whilst the front extremity bears on the frame of the bissel in a line with the carrying axle (fig. 12). This equaliser only acts as distributer of the vertical load, without interfering in the changes of position of the bissel, which continues to be controlled by the tail with its articulation at the back.

The independence of the carrying axle in the general system of suspension exists however in some types; a series of
H. 131 engines, type 131, of the Prince-Henri (Luxemburg), the Uruguay, type 130, and the only series of type 140 of the Italian State which are not fitted with a bissel bogie. The bearing of the main framing is in this case made directly above the carrying axle and in the middle of its length.

In the Prince-Henri arrangement, this bearing is composed of a spherical head resting in a similarly formed centre plate fixed on a bolster swung on vertical links without any additional spring arrangement for initial centreing. The Company states that these engines have been running seven years, they are free from rolling and galloping action, but complain of a vibratory motion at 60 km. (37.3 miles) per hour, and a more rapid wear of the axle boxes than in the other types. It is possible that these inconveniences may be due to the absence of an initial centreing force.

In the two other arrangements, the bearing is made by means of a pivot with flat head let in somewhat (Uruguay), or U. 130
slightly convex (Italian State); the swing I. 140
seating is carried by triangular links and the suspension on the carrying axle effected by means of lateral plate springs on the Uruguay, and helical springs on the Italian State.

Most of the bissels with suspension arrangement connected with that of the first coupled axle have also the swinging bolster arrangement; the pivot slides vertically in a cylindrical guider which is a fixture to the main framing; a long slot allows the entrance of the extremity of the equaliser into a mortice made in the trunk of the pivot; the acting surface of the latter is sometimes flat (French Etat, E.R.U.C. div.
Alsace-Lorraine, Uruguay, Central Argen- S.O.G. div.
tine), sometimes convex (Est, Orleans) and occasionally spherical (Argentine State).

The suspension links of the swinging bolster are of the simple kind (vertical or inclined) on the French Etat, Est and Orleans systems, but on the latter, the centreing force which is nil in the position of equilibrium with these link arrangements, has been provided for by the addition of a spiral spring fixed transversely along the line of the axle.

The triangular links are, on the con-

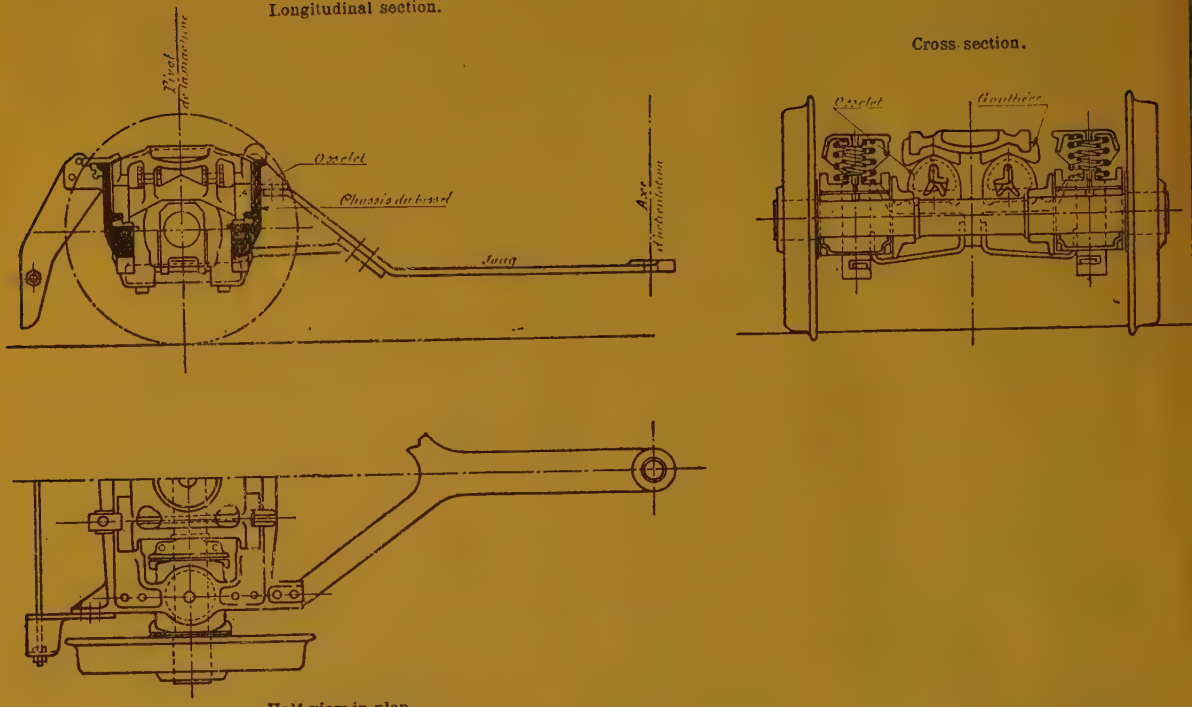


Fig. 13. — Bissel used by the Paris-Orleans Company. — « Woodard's constant centreing ».

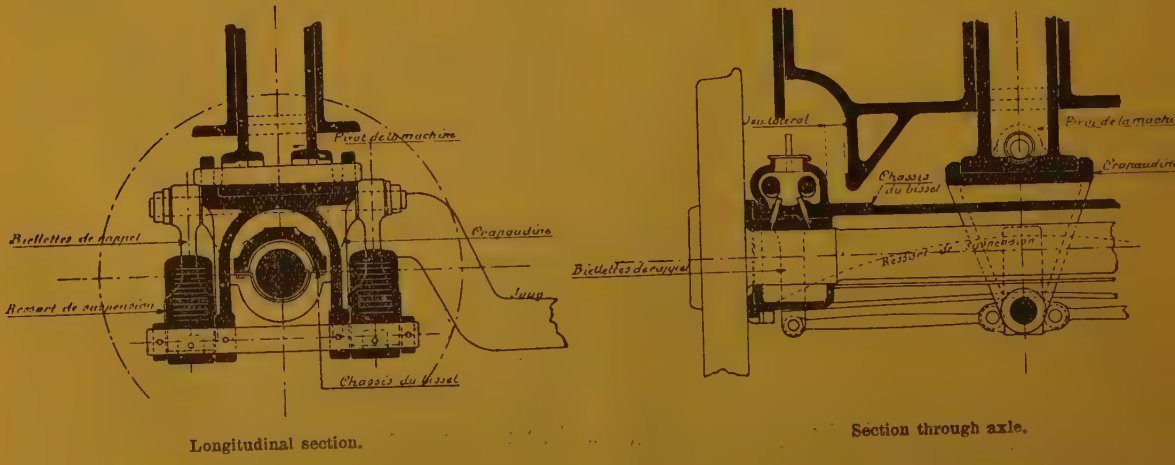


Fig. 14. — Bissel used by the Central Argentine Company. — Lateral centreing arrangement.

trary, in favour in countries of Spanish
t. div. language (Northern of Spain, engines
. 141 140 type of Uruguay, State and Central Argentine). The French Nord also uses them to their complete satisfaction on their recent 141 type of engine. They are also to be found on the Alsace and
. 150 Lorraine engines type 150.

A variant of this arrangement should be mentioned here; this is the «Woodard» bissel with « constant centreing force » (fig. 13) used by the Orleans Company
. 141 in the front and back of its new 141 type. The suspension links of the swing seating are replaced by fittings called « osselets » (knuckle joints) in the shape of equilateral ogives which bear through the pins in their base on to the framing of the bissel and support on their points the centre plate which carries the locomotive. To the bottom part of this centre plate is fixed above each « osselet » a fitting in the form of a gutter placed upside down, of which the inclined surfaces form tangent to the arcs of the ogive of the « osselet » in their slight displacements, the point of contact receding from the summit by degrees so that the leverage of the centreing force remains nearly constant.

The constancy of the centreing force does not appear to be theoretically acceptable, but the apparatus is simple and easy to upkeep, the principal parts working in compression may be left in the rough.

The suspension springs are very generally fixed on the axle boxes of the bissel a special arrangement however should be pointed out in this respect concerning the bissels built by the North British Locomotive Company
140 for the Central Argentine system; in this the swinging seat itself forms the elastic organism (fig. 14), its base being a transversal double plate spring on the middle of which the centre plate takes its bearing, the ends of the spring resting on the bottom pins of triangular links. It is not this however which transmits to the latter the horizontal forces, being duly supplemented in this roll by rigid rods joining the base of its buckle, which is a fixture of the centre plate, to the swinging ends of the links.

In the bissels with pivot and spherical centre plate of the new Paris-Lyons-Mediterranean 141 class engines, which are L 141
also fitted with a connection by means of an equaliser between the carrying axle and the first coupled axle, the centreing mechanism is not arranged with a swing seating and links, but instead with transversal slopes on which the centre plate rises by sliding in its displacements; these slopes are arranged with a spiral surface, having for centre the vertical centre of the swivel of the tail of the bissel.

The bissel of a somewhat special construction (see fig. 15) used by the French N. div.
Nord system comprises a complete framing which fulfils at the same time the roll of carrying as well as that of steering. This framing completely encircles the carrying axle in the transversal movements of which it participates, bearing through the medium of lateral plate springs on the axle boxes on which it is guided vertically by means of ordinary horn plates. It carries towards the middle of its length in a spherical centre plate a pivot susceptible of transversal displacement in slides fixed under the main framing of the engine, these slides being made rectilinear for simplicity in machining. Finally, its back extremity rests by means of a pivot that is also spherical on

a transversal equaliser connecting the front extremities of the suspension springs of the first coupled axle.

Special arrangements are made in order to allow for the slight longitudinal displacements of the back pivot, which are due to the rectilinear shape of the central slides; for this purpose the ends of the equaliser rest on those of the springs by means of a system of two rectangular steel fulcrums making « Cardan » suspension arrangement and allowing the

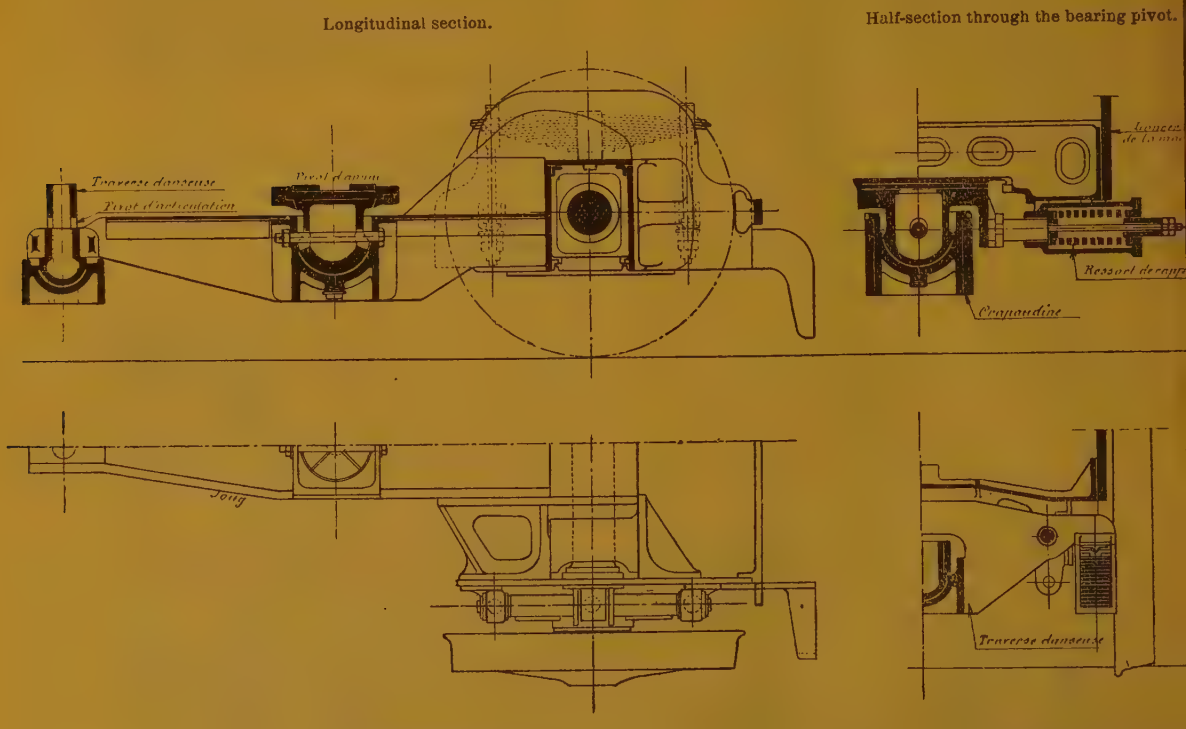


Fig. 15. — Bissel used by the French Nord Company.

equaliser to rotate round a horizontal transversal axis lying some distance above the pivot. Other arrangements consist in lugs fixed to the equaliser towards its extremities and moving in vertical slides which keep the equaliser in position and consequently the swivel in the transversal direction without it having to take a bearing for that purpose on the suspension springs.

The magnitude of the displacements is limited and the transversal displacement made certain by means of stops and adjustable spiral springs fixed in line with the central pivot; the two springs together have an initial compression of

1 500 kgr. (1.476 Eng. tons) and a flexibility of 20 mm. per ton (13/16 inch per English ton).

This combined arrangement may be considered somewhat complicated, so that it may be doubted that the use of rectilinear slides for guiding the central pivot have any real advantage. It appears however to work well in practice, and the Nord Company speaks of it in the following terms :

The various arrangements described give a great stability on straight lines on account of the great initial tension of the centreing springs and allows at the same time rational running in curves, on the other hand the method adopted for hauling the bissel causes this to run very smoothly on the road.

Back bissels. — All that has been already said applies to bissels fixed in front of locomotives; the use of this arrangement for back axles, though common, is not so general, and it must be admitted less interesting. Thus, the Orleans Company in particular only uses on its engines class 231, for its back carrying wheels, simple axles with a lateral displacement of 45 mm. (1 3/4 inches) on each side by means of the play of the axle boxes in the horn plates, and has even discarded, in order to do away with seizing, the inclined centreing planes which were first used and which have been replaced by horizontal friction plates, the front bogie being fitted with a powerful centreing arrangement.

The Italian State system applies the same principle to the back end of its 131 class, whilst the Northern of Spain have retained the inclined centreing planes on its 231 class.

The Midi system has had in use for a long time the same methods, but in its most recent series of the 231 class, it has adopted a bissel supported centrally by means of a spherical pivot in the line of the axle, centreing with triangular links, and suspension by means of plate springs independent of the neighbouring axle.

The back bissels of locomotives, classes 231 and 141 of the Paris-Lyons-Mediterranean, are of the same design, except in the suspension connection with the neighbouring axle, as those described above for the front truck of the new 141 class of the same system.

The Orleans system has adopted back bissels for its new 141 class, but of different types, according as it applies to locomotives with a separate tender, or to tank locomotives, for the first kind the central swing bearing with simple vertical links is used, for the second which have to run indifferently in both directions, this type has been set on one side, the Orleans Company preferring a powerful initial centreing force for the front axles and so have replaced it with a bissel with lateral bearings and centreing arrangement by means of plate springs.

It is this last kind which is in use on the French Est at the rear of their engines, types 141 and 151.

Laterally supported also, bissels fixed at the rear of their engines are used by the French Etat, the Italian State and the French Nord Railway.

As far as the French Etat is concerned there is no idea of abandoning the preference they profess to have for the central bearing for front bogies and bissels, this being really the consequence of the development, which will be dealt with in a further chapter, of the use of equalising

beams in the general system of suspension; the realisation of the principle sought by this Company of the arrangement known as suspension on three points in fact prevents the back and front extremities of a same engine to both bear on central supports. The main framing therefore rests on the bissel at two points by means of springs connected through longitudinal equalisers to those of the last coupled axle.

As concerns the centreing, this is arranged according to the system preferred by the company by means of simple vertical links to which are hung the carriers of the plate spring buckles above the axle boxes. The initial centreing force is therefore nil for both the back and front trucks of these engines, this seems to be the only case of the kind; the total rigid wheel base of these engines however
E. 231 is only 3.95 m. (12 f. 11 1/2 in.).

I. 231 The Italian State has fitted to its 231 class of engine a bissel with lateral bearings and independent suspension springs, but which has no centreing apparatus.

N. 231 The 231 class of the French Nord engines were fitted in the rear with a simple axle which had slight lateral play, but also without any centreing arrangement. A certain number of derailings in running backwards having been attributed to this method of construction, an alteration was made which consisted essentially on the one hand in placing between the buckles of the suspension springs and axle boxes an arrangement of two superimposed crossbeams, one hanging from the other by means of links, and on the other hand to guide the play of the axle, in place of the body of a bissel properly so called with a tail working on a swivel, by fastening the ends of it by means of two horizontally fixed links converging in the same direction to two points fixed symmetrically in relation to the sectional elevation through the centre (fig. 16).

This forms a complicated arrangement, a detailed description of which is outside the scope of the present article and does not appear opportune in view of its origin though the Nord Company express satisfaction with its working in practice.

The back ends of engines, class 141 of N. 141
the same Company, which were constructed in America, are fitted with bissels on the axle boxes of which the engine is supported through the medium of plate spring and vertically jointed rods which connect the ends of these springs to the framing and do duty like the links of a swing bolster. Cases of springs being broken by twisting have necessitated some alteration to the original arrangements so as to increase as much as possible the suppleness and elasticity of the jointed rods.

Axles with circular guiding arrangement. — In connection with the bissels, as eccentrics with crank pins are to be dealt with arrangements which control, without the intervention of a real tail, the freedom of motion of the carrying axle round a vertical axis of rotation. These arrangements are somewhat rare and are only mentioned by the Swiss Federal, the Prince-Henri and the Central Argentine Railways.

The first mentioned have fitted, both
back and front, their new 131 class en- F. 131
gines with it. The colums of the springs which are connected by means of equalisers with those of the neighbouring axle rest on shoes which slide horizontally on the axle boxes of the carrying axle; these boxes, which form the ends of a casing encircling the axle, move in guides which are shaped like a vertical cylinder of 2 m. (6 ft. 6 3/4 in.) radius. The whole ar-

rangement works like a bissel with a tail of this length and is brought back to its mean position by means of two plate springs attached to it.

The arrangement on the Prince-Henri system (engines of the old classes 121 and 131) only differs from this in details and in the springs which are spiral. That of

121 and 131

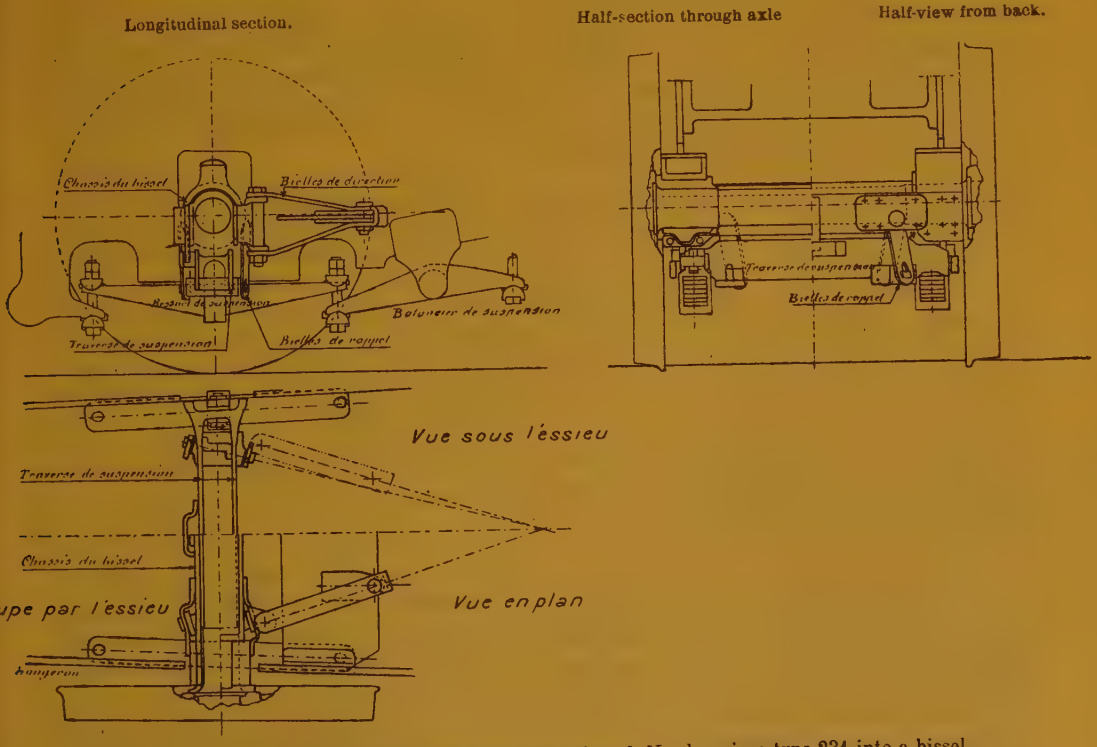


Fig. 16. — Transformation of the back axle of the French Nord engines type 231 into a bissel.

Explanation of French terms: Coupe par l'essieu = Section though axle. — Vue sous l'essieu = View under axle. Vue en plan = View in plan.

the Central Argentine (engines of class 231) is fitted with no centreing arrangement.

231

Amount of play allowed, and magnitude of the centreing force. — The amount of play allowed in bissels, as in the case of bogies, is generally limited by stops. With them the pivot on which they swivel being a fixture of the main framing, the angular displacement is simply proportional to the transversal displacement without necessitating any special arrangement.

As regards the magnitude of the centreing force and the law of its variation in the different systems, we can only refer to what has already been said on the subject of bogies. It may however be pointed out that the centreing force, especially in arrangements with springs, is not always applied in the line of the

carrying axle, but at an intermediary point in the tail of the bissel. It is of course therefore necessary to take this difference of leverage into account in calculating the effects of the centreing force in these cases.

In table III, which is arranged similarly to the preceding ones, interesting and sufficiently precise figures are given relative to different designs of front bissels:

Lubrication. — As in the chapter on bogies, we give below useful extracts from the particulars received :

French Etat. — The parts controlling the various displacements of the bissel are fixed in a construction encircling the axle which is lubricated in the same way as ordinary axle boxes.

French Nord. — The lubrication of the central pivot is assured by means of an injection of grease under pressure to the bottom part of the centre plate.

French Est. — The rubbing surfaces of the slides on bissels with lateral supports are lubricated by means of oil cups with valves which are fixed either on the framing or on the parts themselves. The same arrangement is followed for the guiders of the columns under compression which transmit the weight on to the boxes. Finally the wheel flanges are lubricated by means of felt soaked with oil from time to time by dipping it, and then fixing it, in sheet metal casings, the weight of which induces them to lie against the acting surface of the flanges.

No special arrangement for lubrication is provided in bissels with central bearings, all the parts requiring oiling being easy to get at by hand.

French Midi. — (Bissels with central bearing). The lubrication of the pivot and centre plate, as well as the head of the yokes, is accomplished by means of pipes leading from two oil cups with wool trimmings.

Paris-Orléans. — Gives the same information as for the bogies.

Paris - Lyons - Mediterranean. — The whole arrangement of pivot, centre plate and spiral slopes works in an oil bath, pipes allowing the oil to be emptied and replaced without difficulty.

Prince-Henri. — Axles with play : the sliding cover bears on the axle box in an oil through arranged on the top of the box, holes with wool trimmings conduct the oil to the horn blocks of the radial boxes in the same way as with ordinary axles boxes. Bissels properly so called : the seating of the spherical centre and the joints of the links are oiled by means of ordinary lubricators.

Other systems. — No details.

IV. — Driving and coupled axles.

Arrangements for side play. — These arrangements are somewhat exceptional for driving and coupled axles and have only been referred to in the following cases :

Front axles of locomotives type 050 of the French Midi Company with the total weight utilised for adhesion; the side play of this axle works in combination with a spherical joint on the side rod; after being put to work, a centreing arrangement was added constructed with a spiral spring with initial compression of 1 200 kgr.) 1.18 tons) having the very great flexibility of 90 mm. (3 9/16 inches) per ton; the maximum play is 27 mm. (1 1/16 inches) on either side. The addition of this centreing spring has been the means of lessening the wear on the tyres. M. 050

Back axle of engines type 150 of the French Nord. The maximum displace- N. 150

Table III.

ENGINES.		Wheel base: rigid, in metres.	Wheel base: total, in metres.	Distance of the carrying axle to the next axle, in metres.	Length of the tail of the bissel, in metres.	Maximum displacement: lateral, in millimetres.	Maximum displacement: angular.	Weight: on the bissel, in kilogrammes.	Weight: of the bissel, in kilogrammes.	Weight: total on rail, in kilogrammes.	Centreing force without taking friction into account: initial.	Centreing force without taking friction into account: maximum.	Leverage of this force.	*Remarks.*
							Centreing with plate springs.							
S.	130	3.55	6.00	2.45	1.79	42	1° 20′	11 470	2 110	13 580	1.500	4.286	1.79	
S.	141	5.10	9.84	2.37	1.70	90	3°	11 420	2 800	14 220	3.012	4.300	1.70	
M.	130	4.00	6.60	2.600	1.865	30	1°	9 400	2 400	11 800	2.300	4.300	1.865	
F.	131	3.90	8.90	2.50	2.00	70	2°	...	...	12 100	630	...	2.00	
							Centreing with spiral springs.							
S.	151	6.00	12.00	3.00	2.14	150	4°	11 810	2 630	14 440	3.012	5.254	2.14	
L.	140	6.28	8.78	2.50	1.53	26.5	1°	7 160	1 660	8 820	2.400	3.050	1.25	
N.	140	5.96	8.46	2.50	1.95	55	1° 30′	...	...	10 135	1.430	4.050	1.03	
N.	150	7.62	10.12	2.50	1.95	65	2°	...	...	10 300	1.430	4.525	1.03	
H.	121	2.00	6.80	2.30	1.77	60	2°	10 000	1 250	11 250	2.000	...	1.77	
H.	131	3.60	8.05	2 50	1.60	38	1° 20′	8 700	1 400	10 100	1.150	...	1.60	Class 201-205
							Centreing with inclined planes							
L.	141	5.40	11.05	2.75	2.085	35	2°	9 320	2 380	11 700	2.050	2.050	2.085	(1) Without the additional help of spiral springs.
F.	150	6.45	8.80	2.35	1.70	75	2° 30′	8 800	1 500	10 300	1.050 (1)	1.050 (1)	1.70	
							Centreing with swing seatings.							
O.	140	4.80	7.35	2.55	1.90	70	2°	6 170	2 130	8 300	0	1.440	1.90	
O.	150	6.10	8.65	2.55	1.90	70	2°	6 170	2 130	8 300	0	1.440	1.90	
S.	140	4.90	7.05	2.15	1.72	82	2° 45′	6 560	2 040	8 600	0	2.700	1.72	
H.	131	3.60	8.05	2.50	1.55	45	1° 40′	11 000	2 500	13 500	0	1.500	1.55	Class 206-215
U.	130	3.80	6.15	2.35	2.00	57	1° 40′	p.	...	9 600	0.18 p.	0.50 p.	2.00	
U.	140	4.75	7.05	2.30	1.75	64	2°	p.	...	9 100	0.18 p.	0.54 p.	1.75	
C.	140	4.90	7.35	2.45	1.70	51	1° 40′	4 900	2 600	7 500	600	1.240	1.70	
P.	141	4.95	10.00	2.59	1.68	...	...	p.	...	11 567	0.21 p.	...	1.68	
I.	140	4.50	7.10	2.60	1.68	100	3° 25′	10 500	...	...	2.200	6.480	1.68	
R.	150	6.00	8.50	2.50	1.90	80	2° 25′	10 000	...	...	1.240	3.340	1.90	

ment of which is 20 mm. (13/16 inch.) is obtained by means of play in the axle box bearing and does not involve any special construction for connecting this box with the suspension arrangement; the back coupling rod is jointed with the preceding one by means of a spherical socket; its freedom to rotate at the other extremity is assured by means of a cylindrical knuckle joint surrounding the bearing with its back portion and forming with the bearing itself a sort of Cardanic arrangement. The axle regains its normal position by means of inclined planes 1 in 10. Oil cups supply the necessary lubrication through vertical channels communicating with the surface of the inclined planes which are fitted with grooves.

A similar arrangement is noticed on engines of the same kind belonging to the
O. 150 Orleans system. This Company has recently put on trial a modification of the link system of centreing. Though only one engine has so far been fitted, an improvement in running in curves and a decreased wear of bearings and tyre flanges has been noticed.

The arrangement of the Nord 150 type but with a spherical joint at each end of the coupling rod, is also found on back
L. 150 axles of the Paris-Lyons-Mediterranean 140 type of the most recent construction. This is combined with a thinning of the flanges of the other wheels which is respectively for the first, second and third coupled axles 5, 18 and 5 mm. (13/64, 45/64 and 13/64 inches), whilst the amplitude of the displacement of the back axle is 26.5 mm. (1 1/16 inches). The latest tendency however of the Company is to abandon this system, as it appears to them to be uselessly complicated and replace it by thinning the middle flanges only. This is why the play of the back axle has been done away with on engines types 240 and 230, on which it L. 24
was respectively 27.5 and 8 mm. (1 1/16 L. 23
and 5/16 inches). At the same time the flanges of these engines were reduced by 5, 18 and 18 mm. (13/64, 45/64 and 45/64 inches) on the first, second and third coupled axles of the first type, and 10 mm. (25/64 inch.) for the second coupled axle of the second type.

The French Est Company gives no side play to its coupled axles; it is satisfied with reducing the thickness or even abolishing (middle axle of type 151) the middle S. 141 and flanges, and points out that under these conditions its locomotives of types 141 and 151, in spite of their long rigid wheel base, but thanks to the arrangement of their back and front bissels, run easily in curves, whilst the rigidity of the adhesive portion « is very advantageous from the point of view of the upkeep of the couplings, rods and crank pins, stability in running and less fatigue to the road ».

Other railways give no information on the subject.

Calculation of balance weights. — The rules adopted by the various companies are all based on the distinction between the revolving masses which are always completely balanced, and the reciprocating masses which are only partly balanced in various proportions.

From this point of view it is as well to define at once how the weight of the connecting rods is distributed between these two actions between which it plays an intermediary part. The rules that are followed with this object are always empirical and have never a precise justification: the Est, the Orleans and the Paris-Lyons-Mediterranean allot 2/3 of the total mass, big and little ends included to the revolv-

ing masses; the French Nord allow for these weights the big ends and half the rod; the Italian State distributes it according to the statical distribution of the weight between the centre of the big and little ends; the Midi made use of a more complicated formula imagined by Deharme, which takes into account the position of the centre of the hammer blow.

It will be seen that the practical results of these different formulae do not differ much from one another. The French Etat leave it to the builders without specifying any particular formula.

With four cylinder engines, the two motions on each side of which are generally fixed at 180°, their corresponding parts are therefore reciprocally balanced with sufficient accuracy in practice to enable them in this case to take no special means to balance the reciprocating weights. It has been found that with this method the variation of the weight on the wheels due to the inertia of these masses is negligible, in spite of the slight slope of the inside cylinders in some cases reaching 14 % which is often given to inside cylinders.

With two cylinder engines, on the contrary, the partial horizontal balancing of the reciprocating masses is considered in a general way as a necessity; it is important however not to force this balancing so far that the vertical perturbations which are the direct result reach a prohibitive figure.

Most of the rules in use fix a definite figure which these perturbations must not exceed; the Est allow for this purpose that of the suspended weight, the Orleans, Italian State and the Swiss Federal 0.15 of the statical weight, which according to the details supplied by the Italian State lead to the balancing of 30 % of the reciprocating weights. Other companies, for reasons of simplification, prefer to definitely adhere to the latter fraction; the French Nord to that of 1/3 and the Central Uruguay to 5/8, which appears very large.

The rules proposed by Deharme are much more precise. These are in use on the Midi Railway, though the practical results obtained do not perhaps appear to really justify their complication. They were discussed at the Paris Session of 1900 (question XII), so it seems scarcely worth while to return to this subject now.

It is hardly necessary to point out, that in every case and according to the classical methods adopted, the balance weights for establishing horizontal equilibrium are distributed amongst the various coupled axles in such a way as to reduce the vertical perturbations occurring individually to each one of them, and that each weight is so arranged between the two wheels of the same axle so as to avoid the transversal perturbations.

V. — General suspension.

Suspension springs. — Most of the suspensions springs in use, as much for driving and coupled as well as for bogies, bissels or simple carrying axles, are laminated springs, the arrangement of which and the methods of fixing have no special peculiarity which appear interesting enough to describe here.

They are placed either above the boxes on which they bear directly, or by means of columns, or below the boxes in buckles hanging from the latter, the choice of either system being seemingly only dependent on considerations of available space.

In some cases the plates are greased when put together (French Est, Central

Argentine), but no arrangement has been mentioned to keep this lubrication up in working.

The hangers have also a threaded portion with nut and lock nut which allow an initial adjustment of the tension of the spring and its rectification when in service. The bearing of these hangers on the framing or on the ends of the springs is generally made through the medium of steel fulcrums fixed in such a way as to transmit the action of the spring only in the direction of its normal bending motion.

Spiral springs are only used in exceptional cases, and according to the room that may be available; they are hardly to be found anywhere except on the axles of the following :

Argentine State, front axles of the 141 type;

Central Uruguay, bogies of the 222 type;

French Orleans and Midi, back axle of the 231 type;

Paris-Lyons-Mediterranean, back axle of the 141 and 231 types;

Italian State, first coupled axle of some of the 130 and 140 types;

Paris-Orleans, bissels of certain of the 141 type.

The latter system had also tried spiral springs on its first engines type 231; they decided however not to continue with them on their later engines on account of inconveniences found to occur in working, such as a tendency to bend over, wear of sliding surfaces, etc. The Swiss Federal Railway have also replaced, with plate springs, the spiral springs that were fitted on the locomotives of the old Gothard Company, finding that the latter with their total absence of friction caused excessive oscillation and vibration.

Spiral springs are often made double, the exterior one being of larger section than the one fixed in the inside.

We should remember that the Swiss Federal Railways have successfully used spiral springs in conjunction with plate springs; this arrangement is found on bogies fitted to their 230 type, as well as F. 230
on bissels and bogies of their 150 type. F. 150
It is also found with spiral springs on the Alsace and Lorraine 150 type. R. 150

The principal features of the springs mentioned of the two different kinds are shewn in tables IV and V.

No company has given results of tests for flexibility or of friction between the plates.

As regards conditions of acceptance, these are too complicated to summarise; in the appendix of the present report will be found :

1° The standard technical specifications agreed to by the French railways for the supply of spring steel, plate spiral or helical springs;

2° Similar documents of the Italian State and Swiss Federal Railways.

The North of Spain and Andalous Companies state that they specify according to the French regulations. The Central Argentine follows the English practice. The other companies give no details concerning this subject.

Compensating beams. — The compensating beams or equalisers fixed between the suspension springs are used for purpose of maintaining a constant relation between the various wheels thus connected. A group of wheels connected by

TABLE IV.

a) **Laminated or plate springs.**

ENGINES.	Axles	Number of plates.	Section, in millimetres.	Full length of longest plate, in metres.	Amount of camber, in millimetres.	Deflection, in millimetres per ton.	Normal working load, in kilogrammes.	Weight, in kilogrammes.
N. 221	of the bogie.	13	90×10	0.810	30	7.2	3 500	54
Id.	driving.	15	110×12	1.100	50	6.9	6 500	127
Id.	of the bissel.	15	110×12	1.100	75	6.9	6 500	127
S. 230 (class 3800)	of the bogie.	21	100×7	0.750	12	8.3	...	...
Id.	driving.	12	120×11	1.000	68	7.5	...	...
S. 230 (class 3100)	of the bogie.	23	100×7	0.800	20	9.4	...	...
Id.	driving.	14	120×11	1.000	72	7.5	...	...
E. 230	of the bogie.	14	125×12	1.200	180	9.6	8 850	138
Id.	driving.	15	120×12	1.100	50	7.7	5 760	113
M. 230	of the bogie.	18	90×8	0.753	35	8.0	4 930	51
Id.	driving.	17	100×12	1.200	70	9.7	7 000	126
N. 230	of the bogie.	13	90×10	0.810	30	7.2	3 500	54
Id.	driving.	15	90×12	1.000	60	9.1	5 740	102
L. 230	of the bogie.	16	120×14	...	67	4.8	...	...
Id.	driving.	20	100×10	1.000	70	7.7	6 700	105
A. 230	of the bogie.	9	90×10	0.700	25	6.5	3 100	34
Id.	driving.	12	90×12	1.000	80	8.2	4 840	72
F. 230	of the bogie	13	100×10	0.750	...	4.0	...	...
Id.	driving.	12	100×13	1.200	15	8.8	6 250	...
D. 230	of the bogie.	11	90×10	0.822	40	9.6	3 000	47
Id.	driving.	13	100×12	1.016	85	7.6	6 000	66
N. 232	leading bogie.	19	90×8	0.750	44	6.5	6 700	57
Id.	1st and 2nd driving	17	110×12	1.100	0	6.0	6 700	135
Id.	3rd driving.	17	110×12	1.100	42	6 0	6 700	135
Id.	trailing bogie.	20	110×10	1.000	60	6.6	8 750	120
L. 240	driving.	9	120×15	1.120	39	6.5	6 430	94
E. 231 old.	of the bogie.	17	90×8	0.780	12	8.7	4 500	50
Id.	driving.	15	120×12	1.100	50	6.2	6 700	117

TABLE IV (*continued*).

a) **Laminated or plate springs.**

ENGINES.	Axles	Number of plates.	Section, in millimetres.	Full length of longest plate, in metres.	Amount of camber, in millimetres.	Deflection, in millimetres per ton.	Normal working load, in kilogrammes.	Weight, in kilogrammes.
E. 231 old.	of the bissel.	12	90×13	0.920	35	5.0	7 100	74
E. 231 new	of the bogie.	15	125×13	1.200	200	6.4	9 250	148
Id.	driving.	15	120×12	1.100	50	6.5	7 000	117
Id.	of the bissel.	12	90×13	0.920	45	5.0	7 100	74
M. 231.	of the bogie.	18	90×8	0.753	35	8.0	4 900	51
Id.	driving.	15	120×12	1.100	50	6.6	6 800	118
N. 231.	of the bogie.	14	90×10	0.786	25	5.6	4 000	53
Id.	driving.	15	110×12	1.100	50	6.8	6 500	111
Id.	of the bissel.	11	110×12	1.100	50	9.5	3 850	85
L. 231.	of the bogie.	15	120×15	1.250	46	5.1	...	...
Id.	driving.	16	110×22	1.100	70	6.75	7 680	120
O. 231.	of the bogie.	14	90×10	...	25	5.6	...	...
Id.	driving.	15	120×12	1.200	50	6.2	...	...
H. 121.	all.	10	90×13	0.950	10	...	5 800	...
F. 130.	of the bissel.	9	100×13	1.000	...	...	...	...
Id.	driving.	12	110×13	1.200	15	8.8	6 250	...
F. 131.	leading and trailing.	9	110×13	1.000	...	7.0	...	...
Id.	driving.	12	110×13	1.200	15	8.8	6 250	...
H. 131 old	all.	11	90×13	0.950	...	...	6 200	...
H. 131 new	leading and trailing.	8	100×13	0.700	10	...	5 750	...
Id.	driving.	12	100×13	0.950	20	...	6 500	...
S. 140.	of the bissel.	9	90×10	0.750	30	9.0	...	...
Id.	driving.	14	100×12	1.000	50	6.7	...	...
N. 140.	of the bissel.	13	90×10	0.750	0	5.45	4 150	58
Id.	driving.	15	110×12	1.100	60	6.8	6 890	147
L. 140.	of the bissel.	12	90×10	0.900	66	10.5	...	...
Id.	driving.	8	120×15	1.120	39	6.5	6 430	93
S. 141.	leading and trailing.	24	120×8	1.220	105	17.75	...	...

TABLE IV (*continued*).

a) **Laminated or plate springs.**

ENGINES.	Axles	Number of plates.	Section, in millimetres.	Full length of longest plate, in metres.	Amount of camber, in millimetres.	Deflection, in millimetres per ton.	Normal working load, in kilogrammes.	Weight, in kilogrammes.
S. 141	driving.	13	100×12	1.150	53	9.4	...	...
L. 141	leading.	29	100×6	0.650	35	6.5	5 450	...
Id.	driving.	10	120×15	1.170	45	6.1	7 700	110
G. 141	driving.	10	90×12	0.800	10	...	4 240	...
N. 150	of the bissel.	13	90×10	0.750	0	5.45	4 150	58
Id.	driving.	15	110×12	1.100	60	6.8	6 890	147
F. 150	of the bissel.	13	100×10	0.750	...	..	...	...
Id.	driving.	10	110×13	1.000	15	6.1	6.000	...
S. 151	leading and trailing.	24	120×8	1.220	105	17.75	...	...
Id.	driving.	17	120×10	1.000	50	6.7	...	...
I. all	leading.	11	90×13	0.902	...	5.0	...	...
I. 231	driving.	15	120×13	1.100	...	5.0	...	...
Id.	trailing.	9	130×15	1.100	...	5.0	..	...
I. 130 (class 880)	1st coupled.	(See table *b*).						
Id.	2nd and 3rd coupled.	11	90×13	0.950	...	6.0	...	...
I. others 130	1st coupled	13	130×15	1.160	...	4.5	...	...
Id.	2nd and 3rd coupled.	13	90×13	1.100	...	8.0	...	...
I. 131	1st coupled.	13	130×15	1.160	...	4.5	...	...
Id.	2nd and 3rd coupled.	8	130×15	1.100	...	5.5	...	...
Id.	trailing.	9	130×15	1.100	...	5.0	...	...
I. 140 (class 745)	1st coupled.	(See table *b*).						
I. 140 (class 740)	1st coupled.	11	130×15	1.060	...	4.0	...	...
I. 140	others.	8	130×15	1.100	...	5.5	...	...
R. 150	leading.	8	90×13	0.750	...	...(1)	...	...
Id.	1st, 2nd & 3rd coupled.	9	120×13	0.950	...	...	...	...
Id.	4th and 5th coupled.	General arrangement : see fig. 17.						

(1) The additional spiral springs have an individual flexibility of their own of 14.5 which is added to that, not given, of the plate spring.

TABLE V.

b) **Spiral springs.**

ENGINES.	Axles.	Mean diameter of the spring, in millimetres.	Diameter of the wire, in millimetres.	Number of turns.	Height when made, in millimetres.	Flexibility, in millimetres per ton.	Normal working load.	Weight.
G. 141 . . .	Carrying AR	74-120	16-25	12.5-8	275	37.5	Not given.	
L. 141, 231 . .	Id.	192	37	6.25	365	12.5	Id.	
I. 130. . . .	1st coupled.	79-131	17-30	5.5-3	165	6.5	Id.	
I. 140. . . .	Id.	102-168	22.5-37	7.5-4.5	280	8	Id.	
O. 231 . . .	Carrying AR	90	28 square.	12	435	10	Id.	
M. 231 . . .	Id.							

N. B. — The double numbers in the table refer to cases of double wound springs, the first referring to the inside and the second to the outside winding.

equalisers, whatever may be their number, is equivalent from the statical point of view, and within the limits in which the vertical play of the axle boxes in their horns is sufficient to allow the normal working of the system, to one fulcrum of which the position as well as the distribution of the total corresponding weight between the different wheels of the arrangement, depend solely on the value of the various leverages.

If the number of fixed bearing points so arranged is reduced to three, the distribution of the weight on these three points and from them to the different wheels only depends, at least in theory, on the position of the centre of gravity of the weight in suspension, and avoids the influence, if not those of the perturbations due to the inertia of the working parts, at least the normal variations (rounding curves, changes in gradients) or accidental (defective joints, jumping sleepers, etc...) of the profile, longitudinal or cross wise, of the road.

However, though everybody is agreed on this subject, at least from a theoretical point of view, and taking only the conditions of statical equilibrium into consideration, the practical advantages of equalisers are not unanimously recognised.

The French Etat Company, which is one of its most convinced adherents and makes use of it so far as to fit three point suspension on all its engines (it is impossible to go further without producing unstable equilibrium) recognises that its use is conductive to a certain increase in construction and upkeep costs of the locomotives, but it appreciates the advantage of the constancy of the statical distribution of the load, which is the

basis and condition of a suitable dynamical distribution, and which is produced independently of all weighing and in spite of variations in the elasticity of the springs that may result from the breaking of one or several of the plates.

Other compagnies remain more or less declared adversaries of the use of compensating beams :

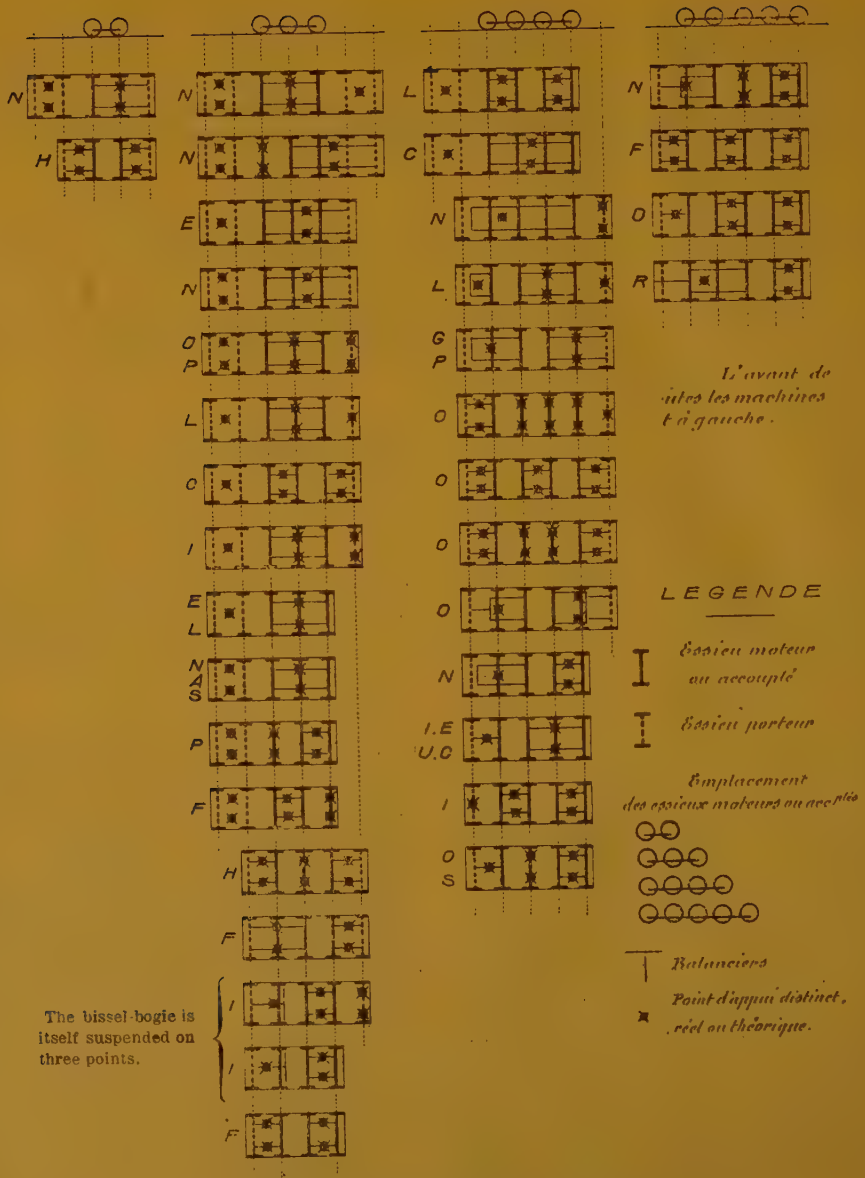
The French Midi considers their usefulness as strongly open to discussion and attributes to them the inconvenience of causing considerable vibration when travelling fast which renders it very fatiguing for the staff on the footplate. Wedging the equalisers to prevent their action on engines types 230 and 231 produced an improvement from this point of view, and reduced the number of hot bearings; locomotives are ordered without equalisers by the Company since this trial was made which dates from 1910, their view not having altered by subsequent experience.

The French Est Company have similar views; if circumstances outside technical considerations properly so called have led them to acquire certain classes of engines fitted with equalisers, most of their locomotives are built without them, they find they are not very effective, especially at fast speeds, not having the time to enter into action with sufficient rapidity; consequently it thinks it best to avoid the complications in construction and upkeep which they bring about, and use instead very flexible suspension springs which make a very good substitute. This Company also complains that they hinder the adjustment of the loads when the design has been responsible for slight errors in calculation which are inevitable, especially when modifications or additions which have been made afterwards have altered the centre of gravity of the engine; the latter inconvenience is especially noticeable when the load limit allowed by the engineers of the line is very nearly reached.

The Paris-Lyons-Mediterranean Company takes this inconvenience into consideration and in such a way that it generally only makes partial use of equalisers and seldom applies the system of suspension on three points.

The Orleans Company points out that springs joined together by means of equalisers slip and break much more readily than springs that are isolated, and that the articulatory parts of equalisers are subject to seizing and rapid wear which renders their action somewhat irregular. However, on account of certain advantages which it recognises, it makes a partial use of them.

Those companies which favour their use, amongst which is the French Nord, do not consider that the draw backs put forwards are very serious, and that at least the advantages considerably overbalance them. The inconveniences experienced by the Midi Company appear to them to be due to an insufficiency allowed in the vertical play in the horn blocks, and that those mentioned by the Orleans Company might be avoided by careful adjustments, especially as regards the lengthening of the hangers. They think that the shifting of the centre of gravity and the errors made in its determination, as pointed out by the Est Company, can only be of small importance, and that the direct visual observation of a locomotive running at full speed is sufficient to show that the compensators act efficiently, from which it may be deduced



The letters placed to the left of each diagram
indicate to which railway the corresponding engine belongs.

Explanation of French terms : L'avant, etc. ... = The front of each engine is to the left. — Légende = Reference. — Essieu moteur ... = Driving or coupled axle. — Essieu porteur = Carrying axle. — Emplacement ... = Position of driving or coupled axles. — Balanciers = Compensating beams. — Point d'appui ... = Distinct points carrying the load, real or theoretical.

that if they do not absolutely insure the instantaneous distributions of the loads, at least their action intervenes in such a way as to cause a mean general equilibrium that approaches it.

Amongst the other companies, that of the Andalous Railway is the only one which does not make use of compensators. However, neither it nor the others which use them give any reason for the motives which have decided them to adopt their particular method. As a practical point bearing on the subject, we find only this observation : « Spontaneous unloading of the weight is occasionally noticed », which the Prince-Henri Railway makes in reference to their 131 class engines which are not fitted with compensators.

In order to illustrate the various views advanced in the above investigation, it appears worth while to insert in the present report the adjoining table, which represents graphically the actual situation of the different types of engines described with this object in the descriptions received, excepting of course those engines which are not fitted with compensators. The resulting theoretical fulcrums corresponding to each group of wheels connected together by means of compensators are however not shewn in a position that has been very accurately calculated, so that these sketches must only be taken as diagrams shewing the number and arrangement relative to those points.

The compensating beam or equaliser is generally made up of a rigid beam, the extremities of which are joined by means of screwed rods to the ends of plate springs bearing on the axle boxes; the framing is carried by them either through the means of fulcrum seatings, friction pins, or by pins, the acting section of which is shaped with a knife edge so as to rest on a hardened and tempered ring. Equalisers are sometimes made with three holes near to one another which makes it possible to make a certain amount of adjustement of the arms of the lever, by placing the beam pin in one or other of the three holes; this arrangement is especially noticeable in equalisers used on the South American Railways.

With another arrangement, much less used and found on the Alsace and Lorraine Railways (back axle of the 150 class) R. 150 the equaliser is made of a plate spring and contrary to the general practice, the rigid pieces bear on the axle boxes, their opposite extremities being held by an arrangement of helical springs (fig. 17).

VI. — Various items.

Engine and tender coupling. — The connection of the engine to the tender for hauling purposes is nearly always made with a screw coupling, through the ends of which vertical coupling pins pass which are kept in position by pieces fixed solidly, one to the framing of the locomotive, and the other to that of the tender. This coupling is not generally connected to springs; only the Algerian State Railway and certain engines of the Orleans system (plate springs), or on the Uruguay system (helical springs) make use of the latter. On the two railways of the Argentine Republic, the coupling bar is rigid without screw ajustement or spring.

The coupling arrangement has often in addition safety couplings (one or two chains having sometimes only one link fixed between two pins).

Buffers on the contrary are nearly always fitted with springs which keep them normally in contact with a certain pressure even in curves, these springs are sometimes arranged independently and

are then generally spiral springs similar to those on carriages. Usually, however, it is a single plate spring fixed in its centre by a buckle attached to the tender framing, its ends bearing on the buffers and working like a compensating beam.

The Orleans Company has successively tried the two systems on its engines class 231, and considers that with the one spring arrangement the running in curves is made easier and the behaviour of the tender on the line improved. O. 231

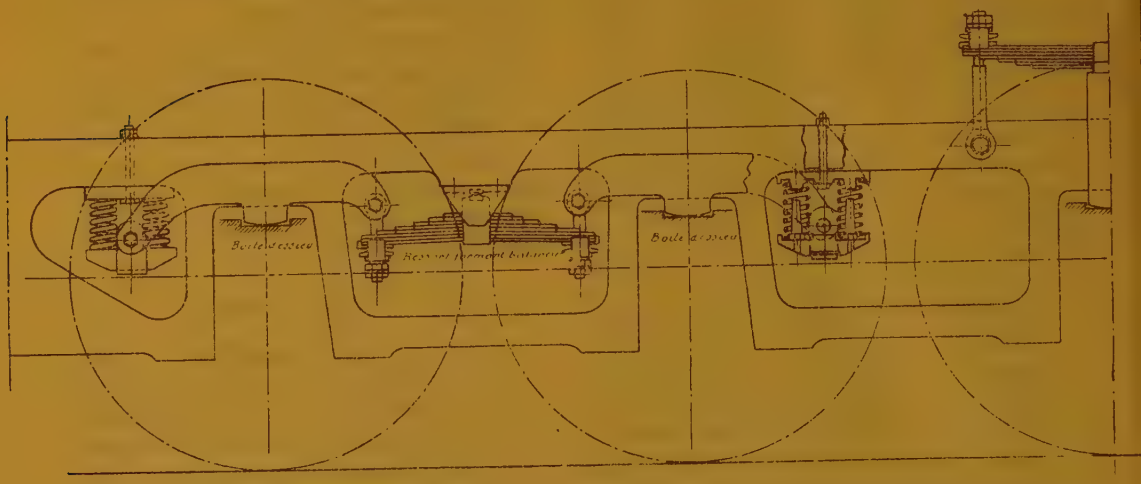


Fig. 17. — Engines type 150 of the Alsace-Lorraine Company. — Suspension arrangement of the back axles.

The Italian State specifies for springs of this kind which it makes use of, the following qualifications :

Flexibility 6 mm. per ton (1/4 inch per English ton).

Initial compression 4 000 kgr. (4 tons).

Stroke of the buffers 55 mm. (2 3/16 inches).

Compression at end of stroke 13 000 kgr. (13 tons).

The Argentine State uses one central buffer fitted with a spiral spring.

On the Central Uruguay the buffer arrangement is also central, but has no spring, contact taking place by means of spherical bearings which fit into one another.

Besides these two cases, there is one in which a buffer is fixed on each side; generally these are parallel to one another and bear on plates with flat surfaces fixed on to the drag beam of the engine and usually are placed normally to the road. The heads of these buffers are flat or slightly rounded; on the long 232 class engines of the French Nord, the buffer heads with large flat surfaces can move round a knuckle joint. N. 23

« Roy » or similar converging buffers are in use on some classes of engines on certain railways (Orleans, Northern of Spain, Swiss Federal). The French Etat makes use of special « Roy » buffers (fig. 18) which allow respectively the back drag beam of the engine and the front drag beam of the tender to make a

horizontal angle of 7°30' (instead of 4°30' given by the ordinary « Roy » buffers); the corresponding tenders are moreover fixed on bogies with link centreing arrangement.

Except the information given by the Orleans Railway and reproduced above, no other details of experimental or practical comparison have been given by the various systems mentioned.

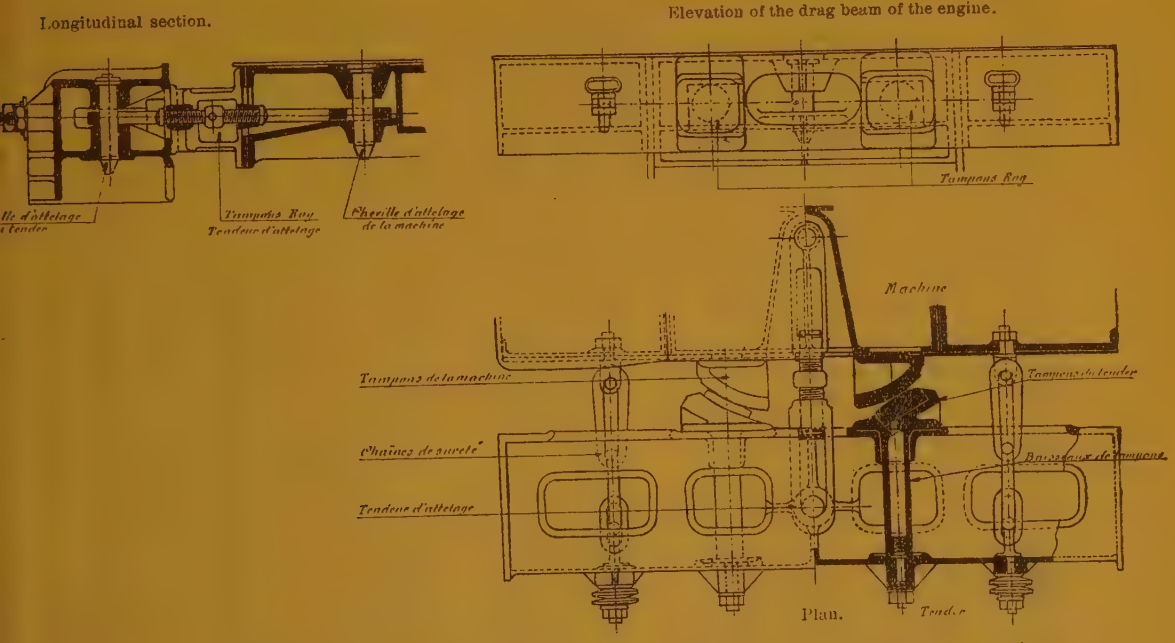


Fig. 18. — Special « Roy » buffers as used by the French Etat Company. — Coupling arrangement.

Special steels. — The use of special steels in order to lighten certain parts of the mechanism and so reduce perturbating action is as yet not general. The only examples which have been given are the following :

Italian State. — Steel with 5 % of nickel for crank axles.

French Est. — Nickel steel for driving crank pins of the 150 class and for the axles of the 230 class.

French Nord. Steel with 2 % of nickel and 0.5 % of chrome for the driving and coupled axles, cranks, lazy cranks and coupling pins; the tensile strength of this metal, which is also very good in resisting the action of friction, is 65 to 70 kgr. per mm² (41 1/4 to 44 1/2 t. per square inch) and its elongation 17 to 18 %; it allows a reduction to be made of 23 % in the weight of the parts in comparison to the ordinary Martin steel.

The latter Company has for some time past made use of an improved method of thermal treatment for carbon steel with excellent results, obtaining a tensile strength of 50 to 60 kgr. (31 3/4 to 38 t. per square inch) and an elongation of 18 to 20 %, at the same time greatly reducing its brittleness and raising its

TABLE VI.

REFERENCE :

Abbreviations in columns 13 et 14 { B. . . = Bogie. / B. b. . = Bissel-bogie. / b. . . = Bissel. / p. . . = Carrying axle. / p. g. . = Axle with radial guides.

Abbreviations in column 20 { D. C. = Double headed rail. / P. . = Flat bottomed rail.

Abbreviations in column 24 { p. f. . = Overhung joints. / j. a. . = Supported joints.

ENGINES.	Number of cylinders.	H.P. Cyl.		L.P. Cyl.		Framing.			Diameter of driving wheels, in centimetres.	Height of the centre of gravity, in centimetres.	Maximum speed, in kilometres per hour	Kind of		Weight on ra in tons.		
		Distance from centre line to middle vertical section, in centimetres.	Incline to the horizontal.	Distance from centre line to middle vertical section, in centimetres.	Incline to the horizontal.	Length, in metres.	Width, in metres	Kind.				Front truck.	Back truck.	Front truck.	Adhesive.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
N. 221	4	107.5	0	30	0	10.90	2.90	Plates.	204	175	120	B.	p.	19.2	36.0	1
E. 230	4	107.5	0	32	0	11.80	2.89	Id.	204	198.5	120	B.	...	22.6	48.9	
S. 230	4	108	0	29.5	0.075	11.20	1.24	Id.	175	...	110	B.	...	21.1	50.1	
S. 230	4	106	0	31.5	0.075	11.80	1.25	Id.	209	...	120	B.	...	24.8	53.1	
M. 230	2	109.5	0	...	...	12.13	3.05	Id.	175	211.7	100	B.	...	22.3	54.0	
N. 230	4	108	0.075	29.5	0.075	10.85	2.77	Id.	175	175	115	B.	...	20.0	51.0	
L. 230	4	108	0	29.5	0.050	11.51	1.23	Id.	180	...	110	B.	...	21.5	50.0	
A. 230	2	104.5	0	...	...	10.70	1.29	Id.	151	...	...	B.	...	15.0	39.0	
D. 230	4	111	0.075	36	0.075	9.95	1.50	Id.	162	...	72	B.	...	17.2	42.8	
F. 230	4	31	...	106	...	10.87	1.32	Id.	178	...	100	B.	...	25.1	47.9	
N. 232	4	111.5	0	19 (1)	0	14.36	2.80	Id.	204	180	120	B.	B.	28.0	55.5	2
L. 240	4	29.5	0	107	0	12.38	1.23	Id.	150	...	...	B.	...	15.4	60.7	
E. 231	4	107.5	0.035	32	0.040	13.62	3.05	Id.	185	195	130	B.	b.	21 0	53.0	1
E. 231	4	111.5	0.020	34	0.020	13.65	3.00	Id.	194	198	130	B.	b.	23.4	55.7	1
M. 231	4	111	0	33	0	13.55	3.00	...	194	...	120	B.	p.	22.3	54.0	1
M. 231	2	110	0	...	...	13.57	3.07	...	194	...	...	B.	b.	20.0	54.0	1
N. 231	4	110	0	32	0	12.05	2.91	Plates.	204	180	120	B.	b.	24.0	49.2	1
L. 231	4	115	0	34.5	0.085	13.30	1.23	Id.	200	199	120	B.	b.	20.3	55.5	1
O. 231	4	115	0.020	34	0.020	13.70	1.25	...	190	180	120	B.	p.	23.2	53.0	1
P. 231	4	...	0.030	37	0.030	12.55	2.90	...	175	...	100	B.	p.	17.2	47.0	1
I. 231	4	27.5	0.012	109	0	12.83	1.29	...	203	...	130	B.	b.	20.0	54.0	1
S. 130	2	101	0	...	...	9.24	1.29	Plates.	142	...	80	b.	...	13.6	40.1	
F. 130	2	104	0	...	...	9.29	1.25	Plates.	152	...	75	B. b.	...	11.3	45.8	
U. 130	2	104	0	...	...	...	...	...	152	...	...	b	...	9.6	36.4	

(1) The two cylinders of 62 centimetres diameter are placed one behind the other.

TABLE VI.

REFERENCE :

ations in 25.

Gr. . . . . = Gravel.
c. . . . . = Stones.
p. c. . . . . = Broken stone.
l. . . . . = Slag.
p. t. . . . . = Soft stone.

Abbreviations in column 27.
V. . = Maximum speed in km. per hour.
c. . = Reciprocal of the radius in metres.

Abbreviations in column 29.
c. . = Circular.
p. . = Parabolic.
p_3 . = Parabolic of the 3rd degree.

pe-ails, li-es. middle.	The worst roadway on which running is allowed.											Remarks.
	Rails.			Number of sleepers per rail length.	Jointings.	Ballast.	Minimum radius of curves, in metres.	Super-elevation.		Connections.	Authorized speed, in kilometres per hour.	
	Type.	Weight per metre, in kilogrammes.	Length, in metres.					General formula, in metres.	maximum, in millimetres.			
19	20	21	22	23	24	25	26	27	28	29	30	31
54	P.	30	8	11	p. f.	Gr.; p. c.; l.	500	90 c.	20	p_3	40	
16	D. C.	39	8	10	p. f.	Gr.; p. c.	500	75 c.	15	p.	100	
30	P.	30	8	10	p. f.	c.; p. c.; l.	300	0.012 V^2 c.	15	p_3	90	Class 3800.
30	P.	30	8	11	p. f.	c.; p. c.; l.	300	Id.	Id.	p_3	90	Class 3100.
. .	D. C.	38	11	14	p. f.	Gr.	500	aV² c. (*)	...	p_3	100	(*) a is a factor which varies according to the line .
19	P.	30	8	11	p. f.	Gr.; p. c.; l.	500	90 c.	20	p_3	...	
46	P.	34	10	12	p. f.	Gr.; p. c.	300	2/3 V. c.	15	c.	...	
26	P.	28	7	8	...	Gr.; p. c.	300	V. c.	...	c.	70	
15	P.	30	8	11	...	p. c.	200	0.014 V^2 c.	...	p.	72	
...	P.	33	6	9	p. f.	Gr.	600	0.7 V. c.	...	p_3	75	
54	P.	30	8	11	p. f.	Gr.; p. c. l.	500	90 c.	20	p_3	...	
62	P.	34	10	12	p. f.	Gr.; p. c.	300	2/3 V. c.	15	c.	...	
16	D. C.	39	12	15	p. f.	Gr.; p. c.	500	75 c.	15	p.	100	Old. / New.
...	D. C.	38	11	14	...	Gr.	500	aV² c. (*)	...	p_3	120	(*) a is a factor which varies according to the lines.
...	...	...	...	...	...	...	...	Id.	...	...	...	Under construction.
54	P.	30	8	11	p. f.	Gr.; p. c.; l.	500	90 c.	20	p_3	...	
40	P.	48	12	18	p. f.	Gr.; p. c.	350	2/3 V. c.	15	c.	115	
25	D. C.	38	5.50	6	p. f.	Sand.	240	0.0118 V^2 c.	...	c.	50	
...	...	32.5	6.20	6	j. a.	Earth.	200	...	...	c.	60	
19	...	...	...	...	...	...	...	...	...	...	...	
45	P.	30	8	10	p. f.	c.; p. c.; l.	300	0.012 V^2 c.	15	p_3	80	
...	P.	33	6	9	p. f.	Gr.	600	0.7 V. c.	...	p_3	75	
..	P.	30	9	...	...	p. t.	400	Table.	...	c.	70	

TABLE VI (*continued*).

ENGINES.	Number of cylinders.	H.P. Cyl.		L.P. Cyl.		Framing.			Diameter of driving wheels, in centimetres.	Height of the centre of gravity, in centimetres.	Maximum speed, in kilometres per hour	Kind of		Weight on r in tons.	
		Distance from centre line to middle vertical section, in centimetres.	Incline to the horizontal.	Distance from centre line to middle vertical section, in centimetres.	Incline to the horizontal.	Length, in m tres.	Width, in metres	Kind.				Front truck.	Back truck.	Front truck.	Adhesive.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
I. 130	2	31	0.140	...	...	9.13	1.29	...	153	...	80	B. b.	...	10.7	43.2
I. 130	2	32.5	0.140	...	...	9.14	1.29	...	185	...	110	B. b.	. .	10.5	44.0
I. 130	2	102.5	0	...	...	8.02	1.29	...	151	...	75	B. b.	...	11.8	39.1
S. 140	4	33.5	0.125	108.5	0	10.82	1.31	Plate.	140	...	60	b.	...	8.6	65.7
L. 140	4	109.5	0	32	0.125	11.90	1.29	Id.	150	...	85	B. b.	...	9.2	63.4
L. 140	4	109.5	0	32	0.125	12.11	1.29	Id.	165	...	95	b.	...	8.5	63.4
N. 140	4	109.5	0	30.5	0.125	11.21	2.77	Id.	155	180	90	b.	...	10.1	72.4
I. 140	2	32.5	0.176	...	...	11.00	1.27	...	163	...	75	B. b.	...	11.4	57.1
I. 140	2	103.5	0	...	...	10.43	1.19	...	137	...	60	B. b.	...	10.0	56.0
I. 140	...	...	...	...	...	...	...	...	136	...	...	b.	...	7.3	56.2
U. 140	2	104	0	...	...	...	...	...	137	...	...	b.	...	9.1	46.5
C. 140	2	120	0.06	...	..	...	...	...	141	...	...	b.	...	7.5	59.8
S. 141	2	109.5	0	...	...	12.64	1.30	Plate.	158	...	90	b.	b.	14.2	58.6
L. 141	4	27.5	0.140	105.5	0	13.12	1.28	Id.	165	...	85	b.	b.	11.7	69.8
G. 141	2	82.5	0	...	. .	9.65	0.85	...	107	...	...	b.	b.	6.8	45.4
P. 141	2	119.5	0	...	...	...	...	...	156	...	...	b.	. .	11.6	59.2
N. 150	4	112.5	0	36	0.125	12.75	2.77	Plate.	155	180	70	b.	...	10.7	88.4
F. 150	4	28.5	0.025	107	0.025	11.24	1.26	Id.	133	...	65	B. b.	...	10.3	76.3
F. 150	4	28.5	0.025	107	0.025	11.24	1.26	Id.	133	...	65	b.	...	10.3	76.3
R. 150	3(1)	0 110	0.165 0	...	...	11.00	1.20	Bar.	140	...	65	b.	...	...	80.0
S. 151	2	109.5	0	...	...	15.90	1.29	Plate.	135	...	60	b.	b.	14.4	89.6
H. 121	2	101.5	0	...	...	9.05	3.04	Id.	159	...	75	p. g.	p. g.	11.2	26.8
F. 131	2	101.5	0	...	...	11.47	1.24	Id.	152	...	...	B. b.	...	...	...
F. 131	2	104	0	...	...	11.47	1.24	Id.	152	...	75	b.	...	...	...
H. 131	2	104	0	..	...	11.70	3.10	Id.	150	...	70	p. g.	p. g.	10.1	45.0
H. 131	2	102.5	0	...	...	11.52	3.10	Id.	150	...	70	b.	b.	13.5	45.0
I. 131	4	29	0.123	...	0	11.13	1.29	...	185	...	110	B. b.	...	11.2	45.0

(1) Three equal cylinders, one of which is on the centre line.

TABLE VI (*continued*).

e-ils, i-s. middle.	The worst roadway on which running is allowed.											Remarks.
	Rails.			Number of sleepers per rail length.	Jointings.	Ballast.	Minimum radius of curves, in metres.	Super-elevation.		Connections.	Authorized speed, in kilometres per hour.	
	Type.	Weight per metre, in kilogrammes.	Length in metres.					General formula, in metres.	maximum, in millimetres.			
19	20	21	22	23	24	25	26	27	28	29	30	31
9	..	27	9	11	p. f.	p. c.	180	Id.	...	...	45	Clas 625.
9	...	30	9	11	p. f.	Gr.	180	Id.	...	...	60	Class 640.
9	...	27	9	10	p. f.	Gr.	180	Id.	...	...	60	Class 880.
5	P.	30	8	10	p. f.	c.; p. c.; l.	300	0.012 V^2. c.	15	p_3	50	
6	P.	34	10	12	p. f.	Gr.; p. c.	300	2/3 V. c.	15	c.	85	O.d (4400).
2	P.	34	10	12	p. f.	Gr.; p. c.	300	2/3 V. c.	15	c.	95	New (3800).
4	P.	30	8	11	p. f.	Gr.; p. c.; l.	500	90 c.	20	p_3	...	
9	...	...	...	...	...	...	...	Table.	...	...	...	Class 745.
9	...	27	9	11	p. f.	p. c.	180	Id.	...	...	45	Class 740.
9	...	30	9	11	p. f.	Gr.	300	Id.	...	...	60	Class 735.
...	P.	30	9	...	...	p. c.	400	Id.	...	c.	70	
...	P.	32	7.50	7	...	Earth.	100	...	...	c.	30	1^m676 gauge line.
0	P.	30	8	10	p. f.	c ; p. c.; l.	300	0.012 V^2. c.	15	p_3	80	
2	P.	48	12	18	p. f.	Gr.; p. c.	350	2/3 V. c.	15	c.	85	
...	...	...	...	...	...	...	...	...	...	...	...	1^m00 gauge line.
...	...	32.5	6.2	6	j. a	Earth.	200	...	...	c.	60	
4	P.	30	8	11	p. f.	Gr.; p. c.; l.	500	90 c.	20	p_3	...	
...	P.	33	6	9	p. f.	Gr.	600	0.7 V. c.	...	p_3	...	Class 2951.
...	P.	33	6	9	p. f.	Gr.	600	0.7 V. c.	...	p_3	...	Class 2970.
...	...	...	...	...	...	...	...	...	...	...	...	
0(1)	P.	30	8	11	p. f.	c.; p. c.; l.	300	0.012 V^2. c.	15	p_3	40	
...	P.	38.5	9	12	p. f.	l.	150	...	...	...	60	
...	P.	33	6	9	p. f.	Gr.	600	0.7 V. c.	..	p_3	...	Class 5801.
...	P.	33	6	9	p. f.	Gr.	600	Id.	...	p_3	75	Class 5828.
...	P.	38.5	9	12	p. f.	l.	150	...	...	...	60	201 to 205.
...	P.	38.5	9	12	p. f.	l.	150	...	...	...	60	206 to 215.
19	...	30	9	11	p. f.	Gr.	250	Table.	...	...	60	Class 685.

(1) axles next to the middle axle, the tyres of wich have no flanges.

elastic limit; the method consists in heating the rough or unmachined piece to 900° (1 650° Fahr.), then plunging it in water at 20° (68° Fahr.) until completely cooled, and afterwards reheating it to between 550° and 600° (1 020° to 1 110° Fahr.) and then allow it to cool in the air.

This treatment is successfully applied to couplings, piston rods and connecting rods.

VII. — Combination of the parts of engines.

After the description of the various parts which constitute locomotives considered as vehicles, the scope of the present report should include an examination of the conditions of grouping of these parts belonging to the various types of engines in service, a comparison of this grouping with other characteristic elements of the same locomotives and the value of the general conditions of stability which results from it.

The authors of the list of questions, very comprehensive in this respect, which was sent to the various railway administrations, seem to have endeavoured to take as a practical basis of comparison for this stability the definition of the worst road on which the running of each type of engine is allowed and the permissible speed at which it may run. This basis is very difficult to define with sufficient accuracy, and the influence of each of the elements which intervene as much in respect to the detrimental effects on the engine as to the resistance of the road is difficult to disentangle. Moreover, the authors of the replies do not appear to have understood the question in the same way, many of them particularly have given only one definition for the roadway, instead of one for each type of engine, or have not stated precisely the reduction of speed which the running of such or such a type of engine involved on the road described.

It only seems possible under these conditions to give in a numerical table the most interesting details of fact given by the various companies in replies more or less complete to the said list of question this information being only of a kind to encourage a more complete investigation of the subject; the ambition to do so does not appear for the present to go beyond the gathering together of some of the elements of the subject which contribute to a preliminary research into the matter.

It is with this object in view we have endeavoured to arrange the table VI.

VIII. — Results of experience or trials.

Outside the value of the results obtained in current practice and mentioned above in connection with the different elements with which they are concerned, the examination of the replies of the different companies does not allow us to give here any but the comparative result of the trials made by the French State Railway in 1912 after two derailings that had happened to engines of the 231 class, the causes of which could not be very clearly determined.

The engines in question were then fitted with Alsatian bogies having lateral bearings sliding on horizontal surfaces and centreing arrangement by means of springs with initial compression. Though this type of bogie was in use on numerous similar engines on various French railways and has been the cause of no accidents in working, it was asked whether the two derailings on the State system could not be attributed to their use.

Such was the origin of the trials that were undertaken and made on an engine of the 231 class which was first fitted with its original bogie, and afterwards with a bogie transformed so as to sensibly conform with the American practice; the alteration also included an increase of 4.75 to 7.25 in the flexibility of the bogie suspension springs as well as increased side play which was raised from 45 to 60 mm. (1 3/4 to 2 3/8 inches) for the central pivot, and from 8 to 20 mm. (5/16 to 3/4 inch) for the back stops; at the same time the coupling with the tender which originally had spring buffers was modified by the adoption of « Roy » buffers allowing large convergence.

Fitted in both ways, the engine underwent trials on a long section of line which was only in moderate condition at speeds varying up to 114 km. (71 miles) per hour, during which were simultaneously recorded the vertical displacements of a point marked on the hanger of each of the springs to right and left of the front axle of the bogie in relation to a gauge mark fixed on the corresponding axle box, that is to say, giving the instantaneous amount of flexion of each of these springs, a flexion that is proportional (in a statical condition) to the weight carried. On the other hand were recorded the lateral displacements of the bogie and of the bissel by noting the blows which were given to the stops when the displacements reached their limit, blows however which rarely happen in practice (with either type of bogie) except in passing over at reduced speed certain contrivances of the road, or (in the case of the transformed bogie), with very feeble intensity when running fast round curves of less than 700 m. (2 296 feet) radius.

The following remarks summarise the opinion of the company that made the experiments on the results of the trials.

The variations of load between the two wheels of the front axle are much less on the transformed engine: the maximum difference reaching 1 100 kgr. (1.08 English tons) (4 400 kgr. [4.33 English tons] on the one side, 3 300 kgr. [3.24 English tons] on the other), instead of 4 000 kgr. (3.936 English tons) (6 100 [6 English tons] on one side, and 2 100 [2.067 English tons] on the other). These figures are relative to the weights on the axle boxes; the differences of weights on the rails are in taking into account the leverages of the acting forces 76/100 of the differences of the loads on the springs.

The lateral displacements of the transformed bogie are greater than those of the original bogie, whilst the corresponding forces are less and more progressive in their action. On the back bissel the shocks and displacements are less with the transformed engine, making it easier to ride on the footplate. These observations relate more particularly to running in curves; as concerns running on the straight, it is recognised that for the original engine as well as for the transformed engine the bogie and the bissel sometimes make, under the influence of vibration, when running fast, greater displacements than when in fairly sharp curves.

After these trials and though the share belonging to each of the above mentioned alterations in the general improvement noticed could not be precisely allotted, the French Etat Company altered the bogies on all its 231 class of engines and adopted, for those since ordered, the American bogie with central bearing and link centreing arrangement. The other companies which make use of the Alsatian

type have doubtless not considered the results of the experiments sufficiently conclusive, for they have not changed their views, no accidents similar to the two derailings on the Etat system in 1910-1911 having occured on their lines.

IX. — Conclusions.

From the whole of the preceding report there does not appear to be any outstanding conclusions to bring forward respecting the different points that have been considered.

On the question of compensating beams especially, the conclusion arrived at in 1900 seems to be the only one to accept now.

As regards bogies and bissels, the question of the central bearing forms part of the same order of ideas and brings forward similar observations; that of initial centreing also shews a divergence of opinion which does not appear to allow of any marked preference to be given to any particular arrangement.

It may be asked if the system consisting of superimposing to the swinging arrangement, with simple vertical links, a special spring contrivance intervening with initial tension should not be considered as constituting a fairly reasonable solution.

This solution would appear to be particularly interesting if practical means were found to rapidly adjust this contrivance before each start, so that it could be possible to vary the power of the initial centreing force according to the degree of sinuosity of the lines run over.

The number of bissel-bogies in use is not sufficient to furnish any conclusive information on the subject.

As regards the bissels or pony trucks, it is better that the length of the tail should be determined so that the axle remains normal to the line when running in curves. It would doubtless be an advantage if the general construction of these contrivances was simplified, which should be quite possible in some of the cases.

Steps are generally taken to avoid giving, at the same time, to the two carrying trucks at the ends of an engine too much freedom.

Concerning the couplings with the tender, the tendency appears to require an absolute rigidity in the longitudinal direction with great suppleness in articulation.

X. — Appendices.

FRENCH RAILWAYS.
(LARGE COMPANIES.)

Conditions of technical standardisation.

No. 8 (11 April 1918).

Technical specification for the supply of spring steel bars.

CHAPTER I.

General conditions.

Classification. — Steel plates destined for making springs are, as regards quality, classed in two categories designated by the letters R and S.

Manufacturing marks. — Each plate is indelibly stamped as near one of its ends as possible with the number of the cast, the maker's mark, as well as with the letter indicating the quality or class of steel.

Example : 250. IY. R.

Manufacture. — Spring plates are made from crucible, electric furnace, or Martin furnace steel.

Appearance. — The plates should be rolled with the greatest care; their surface should be smooth, free from cracks, flaws, ridges, shortness of material or any defect liable to be detrimental to their resistance or to their appearance.

The sections of rolled plates must conform, as regards shape and dimensions, to those shewn on the drawings.

The plates must have a width and thickness which are perfectly uniform. No bulging is allowed across the width, but a slight hollow may be allowed within the limits mentioned below.

The grooves and ribs in those plates which are so constructed should show a well defined section and situated truly along the middle of their width.

Dressing. — The plates should be properly dressed on the flat and at the time of manufacture.

Cutting off the ends. — The ends of the bars should be cleanly sheared and not broken off.

Measuring the section. — The sections, dimensions, position of the grooves and ribs, as well as the hollows in the faces must be checked over with gauges, or by any other method sufficiently precise.

Allowances in the dimensions. — The discrepancies allowed are as follows :

Minimum length of bars ordered to commercial length . . . . . 5 metres.
(Besides the bars that have served for cutting off samples for testing, 10 % of bars of lengths between 3 to 5 m. (9 ft. 10 in. to 16 ft. 5 in.) is allowed).

Length of bars ordered to a fixed length. . . . — 0 / + 5 mm. (+ 0.197 inch).

Width or diameter of the bars . . ± 0 mm. 5 (± 0.0197 inch).

Thickness at the edges . . . . ± 0 mm. 2 (± 0.0079).

Transversal bulging of the faces. 0

Transversal hollowing of the faces (total for the two faces) . 0 mm. 3 (0.0118 inch).

Size of the grooves and ribs . . . ± 0 mm. 25 (± 0.0098 inch).

Position of the grooves and ribs : They must be absolutely in the same diametrical plane and their centres situated not more than 0 mm. 3 from the centre line of the bar.

CHAPTER II.

Nature and proportions of the tests.

Condition of the bars when shewn for inspection. — The bars of each cast must be submitted grouped separately in different sample batches.

Nature and proportion of the tests. — The tests bars are required to undergo are as follow :

DESCRIPTION OF TESTS.		CATEGORIES	PROPORTION OF THE TESTS.
Test for flexibility . . . / Test for rigidity . . . . / Falling weight tests. . .	Plates tempered and annealed like the spring plates.	R. S.	One test per cast.

A test may also be made to determine the amount of phosphorus, which should not exceed seven tenthousandths (0.07 %).

CHAPTER III.

Selection and preparation of test pieces.

Recording the selected pieces. — The chosen pieces are recorded, stamped and marked according to the instructions of the company's inspector.

Shearing the selected pieces. — The pieces chosen for testing are cut off by shearing. If during this operation any spelching, cracks or nicks should occur that might be attributable to a fault in manufacture. all the bars of that cast may be rejected.

Preparation of the selected pieces. — The pieces chosen are, according to their sections, tested with or without re-rolling.

Rectangular bars, ribbed or not, are not re-rolled. The other sections are re-rolled into rectangular bars to a width about equal to six times the thickness.

The selection is only made with bars to a section when ordered $>$ 400 mm² (0.620 square inch).

Stampmarks of the Company. — The test pieces selected must bear the stamp marks of the Railway Company.

CHAPTER IV.

Tests. — Specified requirements.

General condition. — The specified requirements which are given below with each test are the absolute minima.

Every test which does not completely fulfil the specified conditions may cause the rejection of the corresponding batch.

Deflection test.

Selected pieces. — Each test plate is 1 030 millimetres (3 ft. 4 9/16 in.) long (see fig. 19) and is cut rectangular.

Preparation of the plate. — The plate is bent hot to a curve so as to shew a deflection above 40 mm. (1 9/16 inches) at the most to the deflection f corresponding to the elastic limit required.

In the case of ribbed plates, the groove must be on the convex side.

The deflection f expressed in millimetres has been calculated *a priori* by means of the formula :

$$f = \frac{iL^2}{6h},$$

in which :

i represents the elastic elongation which is fixed at :

0.0075 for R steel;
0.008 for S steel.

L the total length of plate in millimetres and equal to 1 030 mm. (3 ft. 4 9/16 in.).

h its real thickness expressed in millimetres, which may differ from the thickness h_0 specified in the order, provided it comes within the limits given in the article on « Allowances ».

Immediately after bending, the plate is tempered and annealed, then trued up if necessary, in taking advantage of the heat left after annealing. After this preparation the plate should still shew a deflection of at least 10 mm. (3/8 inch) above the deflection f.

The operations take place under the conditions of manufacture of the completed spring and according to the methods in use at the works.

Preliminary deflection. — The convex side being turned upwards, the plate is laid on two fulcrums arranged as shewn in figure 19 be-

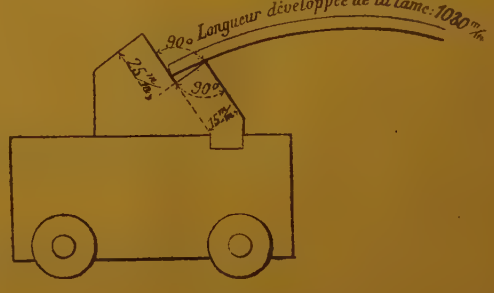


Fig. 19.

low, and carried on two freely running trucks; a weight is then applied at its centre producing a deflection f calculated as described above.

The plate being left thus in tension for five minutes, the load is removed and the new camber measured, which is accepted as the original camber.

Test for deflection properly so called. — After this preliminary preparation, the plate, still resting on its two supports, is gradually loaded at a uniform speed of about 500 kgr. (1 100 lb.) to the minute, without stopping or unloading until the deflection is equal to :

$$f_0 = \frac{i L^2_0}{6h},$$

in which :

i is, as was said before, the elactic limit fixed for the category of steel under consideration.

L_0 the length of the plate under test given in millimetres and equal to 1 000 (3 ft. 3 3/8 in.).

h the real thickness of the plate in millimetres, which may differ from the specified thickness ordered, providing this comes within the limits given in the article on « Allowances ».

The load P_0 corresponding to the deflection f_0 above, is kept on for a minute and then taken off, when the plate must return exactly to its original camber.

If this condition is satisfied, the trial is continued by increasing the above mentioned load P_0 by adding constantly decreasing quantities (50 by 50 kgr., 25 by 25 kgr.), but each time the weight is taken off in order to measure the camber and discover the moment when a permanent deflection begins to take place.

The limit of elasticity is considered to have been reached when this loss in deflection is at the most equal to 0.5 mm. (0.0197 inch).

Elastic elongation. — The elastic elongation i_1 is calculated by means of the formula :

$$i_1 = \frac{6 f_1 h}{L^2_0},$$

in which f_1 is taken as the value of the deflection produced by the load P_1 immediately preceding that which caused the permanent loss in deflection of 0.5 mm.

We should thus find for the elastic elongation values of i_1 at least equal to :

0.0075 for R steel;

0.008 for S steel.

Flexibility. — The flexibility $\frac{f_1}{P_1}$ should have, within the limits of ± 8 %, a value equal to

$$\frac{L^3_0}{4 E b_0 h^3_0},$$

an expression in which :

L_0 is the length of plate under test expressed in millimetres and equal to 1 000,

E is = to 20 000,

b_0 and h_0 are the width and thickness of the plate in millimetres as specified in the order and of which the correct dimensions may differ, providing they lie within the limits given in the article « Allowances ».

Test for counter deflection.

Method of testing. — The trial is carried out by means of progressive loading varying in decreasing quantities until the total deflection reaches 3/2 of the original deflection when made.

Requirements. — This deflection must be reached without rupture.

Falling weight test.

Selection of test pieces. — From the bar chosen for testing, a piece 200 mm. (7 7/8 inches) long is cut off, this is kept straight and hardened and annealed in the same manner as the plates that had been used for the deflection test.

Method of testing. — This short bar is placed horizontally on two supports 100 mm. (3 15/16 inches) apart which are themselves supported on a non-elastic foundation, and is

submitted in its centre to blows given by a block weighing 50 kgr. (110 lb.) working in guides.

The nose of this block is of tempered and annealed steel and is shaped according to the following sketch.

Fig. 20.

The height of the drop H is calculated in centimetres by means of the formula :

$$H = \frac{S}{4},$$

in which S represents the section of the test piece in square millimetres.

The use of a slightly different weight Q than 50 kgr. is allowed on condition that the height of the fall H' is calculated from the formula : QH' = 50 H.

Requirements. — The test bar must resist, without shewing cracks or rupture to :

2 blows for R steel;
6 blows for S steel.

The test is continued until rupture occurs, the number of blows the bar has received being recorded.

No. 10 (11 April 1918).

Technical specification for the supply of finished springs made of parallel plates for locomotives, tenders, carriages and wagons.

CHAPTER I.

General conditions.

Classification. — Springs fitted with parallel plates which include chiefly suspension, buffer, coupling and bogie centreing springs, in flat or ribbed plates are classed in two qualities corresponding to the categories of steel used for their manufacture, namely :

Steel springs in category :

R with an elastic elongation : 0.0075 minimum.

S with an elastic elongation : 0.008 minimum.

Marks of manufacture. — Each spring must have painted on the back plate :

1° The maker's mark;
2° The month and year of its manufacture;
3° Sign reprensenting the quality of metal.

Example : L.M. 3. 18. S.

Manufacture. — The steel bars used in the manufacture of springs should accord in every way with the standard technical specification for the supply of steel spring plates, in accordance with which their acceptance depends before the plates are cut off.

The conditions relating to the construction and flexibility of the springs are shewn on drawings.

The pins holding the plates together are of B quality steel according to the Standard Technical Specification for the supply of round steel rods for rivets, bolts and stays.

The plates must be free from all cracks, seaminess, shortness of material, or any other defect.

The ridges caused in manufacture must be carefully ground off.

The hole destined for the pin which holds the plates together must be carefully drilled with a twist drill, absolutely in the centre of each plate.

Before fastening the plates together, the latter resting one on the other at their ends, the play between them should be in accordance with the quality of the steel and proportional to the length of the plates.

Spring buckles, when used, should be fitted on hot with a maximum play of 2 mm. (5/64 inch). They should be fixed in place at a temperature of bright cherry red (850° C = 1 562° Fahr.) and pressed simultaneously on the four faces with a pressure of about 30 t. so as to prevent slipping in service. It is ne-

ccssary that this pressing on of the buckle should be done rapidly, so that the tempering by means of water which immediately follows this operation is accomplished at a temperature sufficiently high to temper those parts, if any, that have been case hardened. It is important that the buckle should be fixed absolutely in the middle of the spring.

Outside appearance. — All the springs should be perfectly straight transversely, without any twist, and the plates should lie one on another at the edges over their whole length.

The rolled eyelets, if any, must be made absolutely according to the drawing. The centre lines of their holes should be perpendicular to the longitudinal section through the middle of the spring.

Allowances in the camber in manufacture. — The allowance in the camber of the finished spring, as shewn on the drawing, is :

± 2 mm. for a camber equal to or less than 100 mm. (3 15/16 inches).

± 2 % for a camber above 100 mm. (3 15/16 inches).

CHAPTER II.

Nature and proportion of the test.

State of the springs when offered for acceptance. — All springs without exception should, before being offered for acceptance, be tested individually by the makers to the deflection obtained from the specified test load.

They are presented in batches, each of which contains only similar springs.

Nature and proportion of the tests. — The tests to which the springs are subjected are as follows :

NATURE OF THE TEST.	PROPORTION OF TESTS ACCORDING TO THE TYPE OF SPRING.
Deflection tests :	
Under test load. . . .	1 on 10 springs.
— successive loadings	1 — 50 —

Each fraction of a batch may be given a complete series of tests at the request of the Railway Company.

CHAPTER III.

Selection of springs for testing.

Distribution of the springs selected for testing. — The selection of springs for testing purposes is made according to the indications of the Company's inspector from the springs selected by him from the complete batch.

CHAPTER IV.

Tests-requirements.

General condition. — The specified requirement for each test is stated as follows.

Each test which does not completely conform with the conditions specified may result in the rejection of the corresponding lot.

Deflection test.

1° Under test load.

Method of testing. — The first test takes place under the loading conditions fixed on the drawing and corresponding to an elastic elongation of :

0.0065 for R steel;
0.007 for S steel.

In this test the spring placed normally on the testing machine rests through its two extremities on bearings arranged to support it which are fixed on two trucks allowing the spring to elongate during its deflection.

The deflection the spring must take under the action of the test load is that shewn on the drawing; this deflection starts from the position of the real camber of the spring acting freely, and not from the camber shewn on the drawing.

The time occupied for the load test is at least two minutes.

Requirements. — The load having been removed, there must be no loss in camber.

The flexibility of the springs must correspond to that fixed on the drawing with an allowance of ± 8 %.

2° Under successive loadings.

Method of testing. — When placed on the testing machine the spring is submitted to five successive loadings applied step by step until the test load is reached.

Requirements. — The partial deflections must be sensibly proportional to the loadings, and after the test there must be no loss of camber.

CHAPTER V.

Painting.

Immediately after acceptance, the oxide of iron which may have formed on them must be scraped off and the complete outside surface covered with a coat of iron minium paint.

No. 11 (14 November 1918).

Technical specification for the supply of spiral and helical springs for locomotives, tenders, carriages and wagons.

CHAPTER I.

General conditions.

Classification. — Spiral or helical springs, especially those used for buffers, traction or suspension, are entirely made from steel of category S with a minimum elastic elongation of 0.008.

Marks relating to manufacture. — Each spring must have painted on it :

1° The manufacturer's mark;
2° The month and year of its manufacture.

Example : PG. 5. 16.

Manufacture. — Steels used in the manufacture of springs must answer on all points to the standard technical specification for the supply of spring steel bars, in virtue of which their acceptance is effected before they are cut up.

The details of construction and flexibility of the springs are given on the drawings.

Exterior appearance. — Plates for the same class of spring must be all perfectly similar to one another, they must shew no cracks, flaws, shortness of material or any other defect.

The coiling of the springs must be regular, without loss of shape, and comply with the details shewn on the drawings.

The bottoms of helical springs are machined.

Allowances on the dimensions.

IN RESPECT TO :	ALLOWANCES.
Perpendicularity of the centre line of the spring to the plan of base.	Maximum inclination : 2 °/₀.
Parallelism of the two bases.	Maximum inclination : 4 °/₀.
Height of spring . . .	± 2.5 °/₀.
Inside diameter of hole.	± 5 °/₀.
Outside diameter . . .	± 2 °/₀.

CHAPTER II.

Nature and proportion of the tests.

State of the springs when offered for acceptance. — All springs without exception must, before being offered for acceptance, be tested by the manufacturer to the compression or tensile tests specified.

They are shewn in batches containing only springs of that particular type.

Nature and proportion of the tests. — The tests to which these springs are submitted are as follows :

SPRINGS.	NATURE OF TEST.	PROPORTION OF TESTS PER TYPE OF SPRING.
Spiral . . .	Compression test . . .	1 in 10 springs.
Helical. . .	Compression or elongation test . . .	1 in 10 —
	Test under normal loading.	1 in 50 —

The Railway Company may claim a complete series of tests on any fraction of a batch.

CHAPTER III.

Selection of test samples.

Distribution of the selected pieces. — The selection of pieces for testing is settled according to the indication of the company's inspector on springs chosen by him from the whole batch.

CHAPTER IV.

Tests. — Requirements.

General condition. — The specified requirements are indicated below for each test.

Each test which does not completely fulfil the condition specified may cause the rejection of the corresponding batch.

Compression test.

Selection of test samples. — Helical springs working in compression and spiral springs.

Method of testing. — The spring is placed on a flat metallic support, unyielding and non-elastic.

Compression must be obtained by means of the total weight given in the drawing, with an allowance of ± 8 % of this loading unless contrary instructions are given on the drawing.

The time of application of the test load must be at least two minutes.

Requirements. — When the load has been removed, there should be no loss in height.

Tensile test.

Selection of test samples. — Helical springs working in tension.

Method of testing. — Helical springs working in tension are tested with a tensile load corresponding to 1.5 of the normal load shewn on the drawing.

Each spring is kept under the action of this stress for at least two minutes.

Requirements. — The load having been removed, there should be no increase in length.

Test under normal loading.

Selection of test samples. — Helical springs only.

Method of testing. — During the compression or tensile tests, either before or after the application of the full load, the selected spring is submitted to the action of the normal loading shewn on the drawing.

Requirements. — Under this loading the spring should shew the specified flexibility with an allowance of ± 8 %, and when unloaded should return absolutely to its original height or length.

ITALIAN STATE RAILWAY.

Conditions of acceptance of the springs.

A. — Tests of the bars.

Te be carried out on one bar of each batch of 50.

Tensile tests before hardening.

The test pieces must be cut off cold and not be re-heated. Length carefully measured, 200 mm. (7 7/8 inches); thickness of the plate to give a sectional area of the measured portion of about 300 mm². (0.465 square inch).

Test pieces not to be touched with a file, the edges only to be slightly rounded.

Resistance to rupture R between 80 to 90 kgr. per mm² (50 to 57 English tons per square inch.

Elongation L... 12 % minimum.

R + 2 L... 110 minimum.

Deflection tests.

A bar of convention length, bent, tempered and annealed by the same method as that used in the manufacture of the springs, must be placed with the convex side upwards on two knife edges fixed at a distance of about 80 cm. (2 ft. 7 1/2 in.) apart.

After a test for the length of a minute under a load applied in the centre and producing a bending effort of 140 kgr. per mm² (89 English tons per square inch), the amount of camber is measured and considered as initial for the tests which follow.

A second test of same length of time and same load applied by degrees should not produce an appreciable permanent deflection.

The ealstic deflection of the test bar should correspond to a modulus of elasticity of 20 000 kgr. per mm² (12.700 English tons per square inch) at the maximum.

The load on the bar must then be gradually increased until rupture takes place.

The corresponding bending effort should be 230 kgr. per mm² (140 English tons per square inch) at least.

The fracture of the bar should shew a fine and homogeneous grain.

The load P and the modulus of elasticity E are calculated from the formulæ below :

For bars of rectangular section :

$$P = \frac{2}{3} K \frac{bh^2}{l} \qquad E = \frac{Pl^3}{4hb^3\delta}$$

For bars of circular section :

$$P = \frac{1}{8} \frac{\pi d^4}{l} K \qquad E = \frac{4}{3} \frac{Pl^3}{\pi d^4 \delta}$$

k, bending effort per mm²;
b, width of bar of rectangular section in mm.;
h, thickness of bar of rectangular section in mm.;
d, diameter of bar of circular section in mm.;
l, distance between the fulcrums in mm.;
δ, deflection under load P.

The company's inspector may repeat the same tests on any one of the plates which has been prepared for the construction of the springs.

B. — Tests of plate springs.

All springs must be tested under a load corresponding to bending efforts of 90 kgr. per mm² (57 English tons per square inch).

After a first test for the space of a minute, the initial deflection is measured. After a second test in which the same load is gradually applied, and also with rapid and repeated variations under the same load, the permanent deflection should be nil.

The load for the tests and corresponding deflection are calculated from the formulæ :

$$P = \frac{nbh^2K}{6l} \qquad F = \frac{4Pl^3}{Ebh^4} \frac{2l^3 + (l - l_1)^3}{2nl^3 + n_1(l - l_1)^3}$$

P, load on each end of the spring, in kgr.;
F, deflection under load P., in mm.;
K, bending load of 90 kgr. per mm² (57 English tons per square inch);
E, tensile modulus of elasticity : 20 000 kgr. (12.700 English tons per square inch);
l, half the length of the back plate between the points of application of the load, in mm.;
l_1, half the length of the shortest plate, in mm.;
n, total number of plates;
n_1, number of plates of equal length (to the back plate);
b, width of plates, in mm.;
h, thickness of plates, in mm.

An allowance of 10 % above and below is permitted between the calculated deflection and that resulting from the tests.

C. — Tests of helical springs.

The tests are the same as for plate springs. The test load corresponds to a torsional effort of 75 kgr. per mm² (47.6 English tons per square inch). The test load and corresponding deflection are calculated from the following formulæ :

Spring of circular section :

$$P = \frac{\pi d^3 K_r}{16r} \qquad F = \frac{64nPr^3}{E_r d^4}$$

Spring of rectangular section :

$$P = \frac{b^2h^2K_r}{3r\sqrt{b^2 + h^2}} \qquad F = \frac{6\pi nPr^3(b^2 + h^2)}{E_r b^3 h^3}$$

P, load on spring, in kgr.;
F, deflection of the spring under load P, in mm.;
K, torsional load per mm² : 75 kgr. (47.6 English tons per square inch);
E, modulus of elasticity in shear : 8 000 kgr. (5.080 English tons per square inch);

r, mean radius of the spring;
n, number of spirals or turns;
d, diameter of the rod, in mm.;
b, width of the bar, in mm.;
h, height of the bar or rod, in mm.

Note. — The statical loading of springs in service is about half that adopted at the testing for acceptance.

December 1920.

SWISS FEDERAL RAILWAYS.

GENERAL MANAGEMENT.

Extract N° 3 from the specification list for the supply of material for locomotives and tenders.

(1909.)

SPECIAL SPECIFICATIONS.

Art. 15. — Tests for spring steel.

1. — Each individual spring must undergo a deflection test by means of a press; tensile tests must be applied to 1 % of the rolled bars made for the construction of springs.

2. — Under a statical load also of 80 kgr. per mm² (50.8 English tons per square inch) in the direction of the fibre, the spring must, without shewing any permanent camber after the operation, be able to vibrate so that the resulting immediate camber is at least equal to a tensile statical load of 105 kgr. (66.7 English tons per square inch) on the fibre.

3. — Volute springs must be completely pressed home several times without shewing any injury or a permanent loss of height of more than 2 mm. (5/64 inch).

4. — Before tempering, spring steel must shew a tensile resistance of 80 kgr. (50.8 English tons per square inch) with an elongation of 12 %. After tempering, this resistance must equal 110 kgr. (72.5 English tons per square inch) with an elongation of 4.5 %.

5. — Under a statical tensile load of 80 kgr. per mm² (50.8 English tons per square inch) on the fibre, springs made of special steel must, without afterwards shewing a permanent deflection, be able to vibrate so that the resulting immediate maximum deflection is at least equal to a statical tensile load of 120 kgr. (76 English tons per square inch) on the fibre.

6. — Special spring steel must give on test the following results :

Untempered : Tensile resistance, 80 kgr. (50.8 English tons per square inch); elongation, 12 %.

Tempered : Tensile resistance, 145 kgr. (92 English tons per square inch); elongation, 5 %.

7. — Spring plates must have perfectly smooth surfaces and be free from cracks, ridges, faults in material and all other defects susceptible of causing any weakening of the resistance of the metal. The grooves in the plates must be quite sharp in section and truly follow the longitudinal centre of the plates.

Art. 72. — Springs and their suspension.

a) *Plate springs.*

1. — The various spring plates must be bent exactly to the arc of a circle, then trimmed so that when put together with slight pressure they should be a good fit over their whole length.

2. — The trimming of the plates must cause no mark on the metal.

3. — Spring plates must be guaranteed against any slipping.

4. — The eyelets of the back plates must be truly made and parallel to the longitudinal centre line of the spring, and parallel to the bearing surface of the buckle.

5. — Each spring blade must be stamped at a prominent place on the width of the bottom surface with the maker's mark and date of delivery, in letters 10 mm. (3/8 inch) high, it is forbidden to stamp any marks

whatever on the top face of spring plates with the exception of those with rolled eyelets, which may be stamped on the surfaces of the latter.

6. — Spring plates must be tempered uniformly and must not shew any cracks in the edges or longitudinal fissures or any other defects.

7. — Bending and tempering must be accomplished in one heat of the plate.

8. — Before putting together, the surfaces of the spring plates placed one on the top of the other, must be carefully coated with a mixture of tallow and oil, or else with a varnish of tar.

9. — Spring buckles must always, as far as it is possible, be welded on the side opposite to the surface under pressure. If the structure of the buckle does not permit of this method of construction, the stamping process is allowed. In forging the buckles, care must be taken to prevent any cracks or lamination taking place in the interior angles. When it concerns suspension springs fitted with jaws with circular ears, the latter must not be welded or slotted, but should be forged.

10. — Closed buckles must be fitted hot, at a temperature of dull red on to the finished spring.

11. — Buckles which show any cracks after being fitted on must be replaced.

12. Before being fixed on to the springs, buckles must only be machined in the interior of the box and on their two front faces, any other machining required must be done after they are fitted in place. The bottom supporting face of the spring buckle must be exactly parallel to the section through the bearings of the hangers, or in the case of back plates with eyelets, through the centre of the suspension links. The two arms of a spring must be of equal length.

b) *Helical springs.*

1. — All the turns of a helical spring must exactly follow the outline of a screw, so that the pitch of each turn shall be the same and according to the drawing.

2. — In order to increase the bearing surfaces, the top and bottom spirals must be slightly bent back.

3. — In volute springs of rectangular section, the largest and the smallest spirals must be uniformly reduced in thickness and width according to the drawing.

4. — The two bearing surfaces must be parallel to one another and perpendicular to the longitudinal centre line.

5. — After forging or rolling, any ridges that may be apparent must be removed.

6. — Helical springs must be tempered with care, and then show no longitudinal splits, cracks at the edges, or any other defect.

7. — Each spring must be very visibly stamped with lettering 10 mm. (3/8 inch) high shewing the maker's mark and date of delivery.

8. — The height of spiral springs must not vary more than 2 mm. (5/64 inch), above or below. The corresponding springs must be of equal height and of the same carrying strength.

9. — The variation in excess in the height of volute springs must not exceed 5 mm.

10. — Helical springs must be tempered in a mixture of oil and tallow.

Art. 6. — **Guarantee**.

The manufacturer guarantees the perfect working, as well as the quality of material used, during a period of four years, counted from the day of definite acceptance. Until the termination of this period, he is expected to replace, at his own cost, any parts which in normal working have developed defects due to defective material or to bad workmanship.

[625 .14 (.01)]

SUPPLEMENT TO REPORT No. 2 [1]

(All countries, except Denmark, Sweden, Norway, Great Britain and America)

ON THE QUESTION OF THE CONSTRUCTION OF THE ROAD BED AND OF THE TRACK (SUBJECT I FOR DISCUSSION AT THE NINTH CONGRESS OF THE INTERNATIONAL RAILWAY ASSOCIATION) [2],

By Mr. HENRY,
ENGINEER IN CHIEF OF THE PERMANENT WAY AND WORKS OF THE FRENCH EASTERN RAILWAY.

and

Mr. CANDELIER,
ASSISTANT CHIEF ENGINEER OF WORKS AND OF THE SUPERINTENDANCE OF THE FRENCH NORTHERN RAILWAY.

Figs. 1 to 11, pp. 256 to 267.

Question I which is specially concerned with the construction of the road-bed has not been followed as closely as we could have desired since the last conference.

It has not however been lost sight of, even in the districts of the North and East, despite the events of 1914-1918.

A list of questions was sent at the end of last year to the railways.

We have received the following replies :

BELGIUM.

Railway from Malines to Terneuzen.

National Light Railways Company. — The first of these companies has not observed any deformation of its road-bed; the second, which only works light railways, is not in a position to furnish any valuable information.

SPAIN.

The Andalusian Railways have no conditions on their railway system which enable them to give information relative to the question.

The Medina del Campo-Salamanca Railway Company have not observed any deformation of the road-bed.

On this line no trains are run of which the locomotives are very heavy or in the composition of which heavy vehicles are included.

Finally, the line does not cross any marshy, shifting or unstable ground. In addition the trains only travel at a moderate speed.

ITALY.

Italian Public Works Company (Circum-Etna-Catania Railways). — The line

(1) See *Bulletin of the International Railway Association*, October 1920, p. 639.

(2) This question runs as follows : « Arrangements to be adopted in constructing the road bed and the track, in view of the increase in the weight of locomotives and the speed of trains ».

is established on volcanic ground : no drainage work was required. The only deformations observed are due to the penetration of the top ballast into the road-bed on embankments.

LUXEMBURG.

Prince Henry Railways and Mines. — There are no lines permitting of the collection of information relative to the question.

NETHERLANDS.

Dutch Railway Company. — Deformations of road-bed on the lines of this Company appeared during construction. They have not continued to appear, and with increased traffic and heavier vehicles the road-bed has not been further affected.

The embankments, often of considerable height and partially sunk in the bad ground, consist of sand : they are of such bulk that the moving loads have very little effect on them.

PORTUGAL.

National Portuguese Railway Company. — This narrow gauge track cannot supply any particulars of interest.

Portuguese State Railways. — The lines are established on firm ground and have not required special constructional work.

SWITZERLAND.

Swiss Federal Railways. — The lines have been constructed on firm ground; no deformation has been observed.

GREECE.

Bernese Alps Railway Company. — There is no section of the line of this Company that presents matter relative to the present question.

Greek State Railways. — Heavy locomotives are not used and no deformation has been observed.

Medina del Campo-Zamora Railway Company (Spain), *National Railways and Tramways Company* (Italy), State Railways (Serbia-Croatia and Slovenia), and, in Switzerland, the *Yverdon Sainte-Croix Railway*, the *Lausanne-Ouchy Railway*, the *Viège-Zermatt Railway* and the *Rhaetian Railways*, are not interested in the question.

In France, the French Eastern Railway, which furnished extremely interesting information in 1914, has continued its work on the methods already described, and has nothing fresh to add at present.

On the other hand :

The Indian Netherlands Railways (Dutch Indies);

The Italian State Railways;

The French State Railways;

The Paris-Lyons-Mediterranean Railway Company;

The French Midi Railway;

The Orleans Railway Company;

The Paris Ceinture Railway Company;

The French Northern Railway Company, and

The Alsace and Lorraine Railways;

have all contributed instructive information of which an abstract is given in Appendix II of the present report.

In our previous report we wrote that the question put forward seemed to concern only a small number of railway Administrations.

The new inquiry confirmed this theory. We think, however, that from the results obtained on different railways on which the road-bed was to be consolidated in order to counteract track distortion under the present heavy loads, it should be possible to draw conclusions of value to en-

gineers responsible for the maintenance of the track or for the construction of new lines.

Deformations of track and their causes,

At the 1914 conference we described the deformations that occur in the cuttings as well as in the embankments in bad country. We then analysed the causes. We have nothing further to add to this analysis.

CONCLUSIONS.

Preventing deformations,

Reduction of pressure on the road-bed is obtained, as we have stated, by increasing the number and size of the sleepers. A very good means of reducing the intensity of the load by increasing the thickness of the ballast under the sleepers is to introduce a layer of small grain material between the ballast and the clayey road-bed.

Fine slag, and chiefly sand (sand from dunes or rabbit warrens), are satisfactory for this purpose in the majority of cases. The fine sand spread over the wet clay first absorbs the water by capillarity from the earth over which it is distributed; the clay thus dried hardens and can support the load without distortion if it is held laterally along the ditches of the cutting by a solid abutment, as in the dwarf retaining walls used successfully on the Paris-Lyons-Mediterranean Railway. The rain-water, after having passed through the ballast of the superstructure is retained by the fine sand without being able to reach the clay below, provided that the bed of sand is of sufficient thickness. When the rain ceases and the weather becomes dry again, the sand loses its dampness by evaporation and again becomes ready to absorb fresh quantities of rain-water. Lastly, fine sand when compressed and presenting no openings is not penetrated by clay.

In the case of particularly bad country a casing of concrete, made of good materials and Portland cement, constructed on a road-bed at a suitably low level and when no traffic is being carried, appears to afford the solution.

The concrete casing should be sufficiently thick, about 0.20 m. (8 inches). Its surface should be arranged with an inclination of about 3 cm. per metre (3 per cent) transversely, towards the masonry drains which should serve as an outlet for the rain-water which may have penetrated through the superstructure. The concrete should be sunk to a sufficient depth below the rail, in order that it may be possible to cover it with a protective mattress about 0.15 m. to 0.20 m. (6 to 8 inches) thickness of slag, which is produced in abundance in all railway districts : the ordinary ballast 0.20 m. to 0.25 m. (8 to 10 inches) thick will rest on this protective layer under the sleepers.

In this method we have an extremely efficient solution, but a very expensive one; it should obviously only be used in very exceptional cases.

To sum up :

Cuttings. — In the case of clayey cuttings, a mattress of 0.20 m. (8 inches) thickness at least, in fine sand (dune or rabbit warren sand), held on each side by low retaining walls built into fresh and not dug up clay. The whole to be completed by deep lateral ditches, and if the quantity of water is particularly heavy, by longitudinal drains placed between the tracks (in the six foot way). Fine slag of 0.30 m. to 0.40 m. (1 foot to 1 ft. 4 in.) thickness may be substituted

for sand if unobtainable. If the clay is particularly liable to flow, a casing of cement concrete is used, of a thickness of at least 0.20 m. (8 inches). The traffic is suspended until the concrete has set sufficiently. The top of the casing is finished to a slope of 0.03 m. per metre (3 per cent) towards the masonry drains; it is provided with a layer of slag at least 0.15 m. (6 inches) in thickness, on which the usual bed of ballast rests.

In all cases it may be advantageous to increase the number of sleepers, according to the weight and speed of rolling loads.

In the construction of new lines, the operation of making cuttings in clayey country should be carried out in such a manner as to provide for a mattress of fine sand or slag, arranged between dwarf retaining walls or masonry ditches, and also for the concrete casings with their drainage outlets. The arrangements will differ according to the degree of inconsistency met with at the surface of the road-bed.

Embankments. — We have nothing to add to the remarks made in 1914 on the construction of embankments and on the manner in which they may be drained in the event of deformation.

APPENDIX I.

Detailed list of questions relating to question I.

A. — General information.

Ruling gradients.

Minimum curves.

State if the line is double or single.

Maximum running speeds (taken from speed-diagrams) :

for passenger trains;
for goods trains.

Maximum effective speeds on the straight.

Maximum effective speeds on curves of minimum radius or at special places.

Annual tonnage in each direction of traffic, including hauling weight and hauled weight (information to be given at least approximately).

Number of trains in each direction per annum. (State the number, if any, that are double-headed) :

a) *Express* passenger trains;
b) Local passenger trains;
c) Goods trains and light engines.

Average number of vehicles or axles per passenger train.

Average number of vehicles or axles per goods train (including engines, tenders and brake vans).

Extremes of temperature during the year : maximum, minimum.

Average rain-fall per annum (in millimetres).

B. — Information regarding the running of heavy loads.

Sketches showing the loads on and the spacing of the axles for each type of heavy locomotive (at least 16 tons per axle) running on the line, including their tenders.

Sketches showing the loads on and the spacing of the axles for each type of heavy wagon (at least 13.5 tons per ordinary axle or per bogie-axle) running on the line. (Give the minimum distance between the adjoining axles of two consecutive wagons and, in the case

of double-bogie wagons, the distance between the last axle and the buffer.)

Number of heavy locomotives running daily on the line :

1° Hauling passenger trains :

a) Express;
b) Local;

2° Hauling goods trains;
3° Running light.

Average number of heavy vehicles per passenger train.

Average number of heavy vehicles per goods train.

C. — Constitution of the road-bed.

Nature of the earth composing the road-bed. (In the case of an embankment, state also the nature of the ground on which it is deposited.)

Method of draining the road-bed.

Drainage works executed (with sketches).

Cross section of the road-bed (with sketches) :

On embankment;
In cutting.

(Indicate the special sections, if any, applicable to curved portions of the line).

D. — Permanent way.

Weight and length of rails.

Number of sleepers per metre run, width and thickness of the sleepers.

Sketch showing the spacing of the sleepers over a length of rail.

Nature and thickness of the ballast under the sleepers.

E. — Facts observed.

1° Deformations of the road-bed (undulatory deformations, displacement of the side-ditches, etc.) ;

2° Dancing sleepers with eruptions of mud;

3° On embankments, gradual penetration of the ballast into the embankment, formation of pot-holes, etc.

F. — Works executed.
(With sketches.)

Removal of clay. (Indicate the depth to which this has been carried, and the alterations that it has entailed on the side-ditches; give the cross section.)

Drainage :

a) Open drains in masonry or concrete. (State whether it has been found necessary in the case of cuttings to construct very deep open side-drains in concrete with the object of allowing the transverse inclination of the road-bed to be steepened without increasing the width of the cutting; and give the design of the open concrete drain adopted in such a case) ;

b) Longitudinal catch-drains. (Say whether they have given quite satisfactory results, especially the catch-drains laid in the middle of the six-foot way) ;

c) Transverse drains, etc.

Mattresses of sand or of ashes.

Mattresses of concrete, reinforced or not.

Slabs of reinforced concrete, etc.

Increase in the number of sleepers.

Increase in the thickness of the ballast, etc.

Special measures adopted at the crossing :

a) Of bog-land;

b) Of ground which settles on a large scale owing to the compressible nature of the sub-soil.

Lastly, we ask as general conclusions that the rules be given for the construction of new lines which are designed to carry heavy traffic at very high speeds : dimensions to be adopted for the road-bed, the ditches, the ballast, etc.; immediate measures to be taken for the protection of the road-bed.

APPENDIX II.

Summary of Answers received from the various Railway Administrations.

Dutch Indies Railways.

The Netherlands Railways hare conrtibuted interesting information concerning their narrow gauge line between *Goendih* and *Surabaya* in Java.

Although the line is almost wholly on embankment, we think that it should be mentioned here :

Maximum grade . . . . . 5 mm. per m. (5 $^{00}/_{00}$
Minimum radius . . . . . 25 chains.

Single track :

Speeds : Mixed trains . . . . . 24.8 miles per hour.
Speeds : Goods trains . . . . . 15.5 —

Maximum speed on the straight . 34.2 miles per hour.
Annual tonnage : 1 327 000 t. for both directions of traffic.
Average number of axles per train ; 40.
Average rainfall : 2 000 mm. to 3 000 mm. (78.74 to 118 inches).
Maximum axle load of engines : 8.1 t. (8 English t.).
Ditto of heavy coaches ; 8.7 t. (8.56 English t.).
Nature of the ground : marl.
Method of draining the water : sloped road-bed, lateral ditches.
Rail of recent type weighing 38 kgr. per m. (76.60 lb. per yard) and 9.60 m. (31 ft. 6 in.) long carried on 14 sleepers.
Ballast : crushed stone of a thickness of 15 cm. (6 inches) under the sleepers.

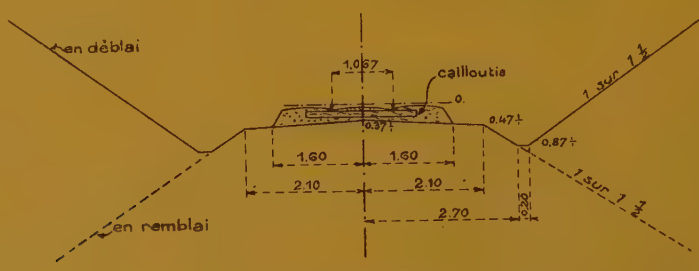


Fig. 1.

Explanation of French terms: En déblai = In cutting. — En remblai = On embankment. Cailloutis = Broken stone ballast. — 1 sur 1 1/2 = 1 in 1 1/2.

Facts observed. — At first, no drainage work was performed. After being at work many deformations occurred in the track, particularly during the early years : horizontal displacements and extension of the road-bed took place producing many rocking sleepers throwing up mud.

Work executed. — The work carried out on the embankments consisted of the establishment of transverse drains of a size varying between 0.60 m. and 2.00 m. (2 feet and 6 ft. 6 in.) placed at points where slipping had already become apparent : the bottom of the drain was made to a slope of 1/6 to 1/10 to facilitate the clearing of the water. Transverse drains of 0.40 m. (1 ft. 4 in.) wide were similarly used in the ballast bed.

Two such drains were made in the road-bed and in the ballast to each length of rail affected by movement. The base and the sides of the drains were faced with hard « Dhook », fibre taken from a particular kind of palm.

The surface of the ballast had to be restor-

ed in places on account of the crushed stone having penetrated the road-bed; so that instead of using 1.2 m³ of ballast per metre (1.41 cubic yards per yard) of track, it was required 3 m³ per metre (3.59 cubic yards per yard).

Conclusions. — The thickness of ballast under the sleepers should be at least 0.40 m. (1 ft. 3 3/4 in.).

The embankments should be built in rammed down layers and should have a slope of 1 in 1.50 at least. Embankments exceeding the height of 5 m. (16 ft. 5 in.) require to be provided with terraces of 1.50 m. (4 ft. 11 in.) wide at each 5 m. (16 ft. 5 in.) of the height. If the material of the road-bed is not sufficiently permeable it is necessary to provide drains.

Italian State Railways.

The general management of the Italian State Railways has replied in detail concerning the following lines : *Empoli-Chiusi, Avellino-Rochetta-San Antonio, Parma-Spezia, Bologna-Padua;* the first three are single tracks, and the last double.

On this last line, in particular, the passenger trains attain a speed of 49.7 miles per hour, with a maximum of 56 miles per hour on the straight. Heavy locomotives are not employed : the weight per axle is under 16 tons.

The *Bologna to Padua* line has rails 9 m. (29 ft. 6 in.) long weighing 46 kgr. per m. (92.73 lb. per yard) carried on 17 sleepers.

Facts observed. — On certain embankments the ballast has sunk into the road-bed; the banks have become distorted, provoking various troubles in the retaining walls. In the cuttings it was observed that clay had pressed up through the ballast and fissures had formed in the retaining walls.

Work executed. — Improvement of the embankment was attained particularly along the *Parma-Spezia* line by the use of transverse drains, cut to a great depth and filled with crushed stone and coarse gravel, communicating with a large conduit at the base leading the water into a longitudinal catch-water drain at the foot of the embankment.

On the *Bologna-Padua* line the old road-bed should be almost completely replaced, by substituting sandy material, gravel, and, sandy gravel drawn from the river-bed of *Reno* for the solid clay earthwork.

In several cuttings on the *Empoli-Chiusi* line the water was afforded outlet by means of several drains placed transversely and one longitudinally under the road-bed. Thus water was released on the outside of the cutting. The whole was completed by a filling of stones under the ballast.

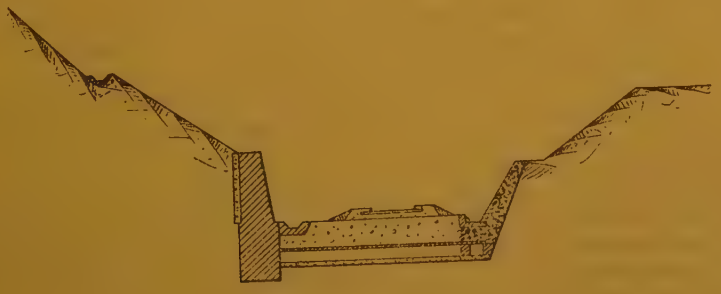


Fig. 2.

Results obtained. — The drainage work carried out on the embankments has produced solidity of the road-bed and has put a stop to distortions.

As to the cuttings, in spite of what has been done slow movement of the road-bed is still taking place.

French State Railways.

The French State Railways Department, taking up and completing the information supplied in 1914, has written as follows :

« In proportion to the increase of the wheel-load of the locomotives (an increase that has been particularly noticeable during the last fifteen years) it has been necessary, in arranging the track, on the one hand to increase the number of sleepers, which are spaced at intervals of about 0.67 m. or 0.80 m. instead of 1 m. (2 ft. 2 3/8 in. or 2 ft. 7 1/2 in. instead of 3 ft. 3 3/8 in.) and on the other hand to increase the thickness of the ballast under the sleepers. This thickness has attained to 0.20 m., 0.25 m. and even 0.30 m. (8, 10 and even 12 inches). This applies to a normal track and sound road-bed, suitably prepared for the drainage of water, both due to springs and to weather.

« It is only during the last twenty years that the problem of the maintenance of the track in cuttings of a clayey and loamy nature has become acute, that is to say at about the time when the weight of the locomotives was greatly increased.

« Nevertheless, the usual troubles that the presence of clay causes at the bed of tracks in cuttings not adapted to the traffic were already apparent. It was hoped at this period to find the remedy for these troubles by the adoption of a drain-forming support of crushed stone of about 0.20 m. (8 inches) in thickness.

« The crushed stone support for the ballast, sometimes continued along the surface of the track, sometimes discontinued, forming a drain, was tried about 1898, particularly in the doubling of the line between Caen and Cherbourg. It did not take long to recognise however that this did not constitute a remedy for the situation : on the contrary, it enabled the rain-water to penetrate into the adjacent clay, which being undermined by it caused further troubles.

« About this same time, the growing requirements of the railway traffic led to considerable improvement in the locomotives.

« With the creation and standardization of the *Pacific*, *Consolidation* and *Prairie* types, the weight per axle increased from 13 and 15 t. to 17, 19 and 20 t., and the total concentrated weight increased from 40 and 55 t. up to 60, 75 and even 100 t.

« The immediate result was a disturbance in the equilibrium of the various details of the permanent way particularly in clayey cuttings.

« The load on a sleeper in consequence of the interposition of ballast provided with elasticity, is distributed on the ground in such a manner that the pressure is distributed from A to B.

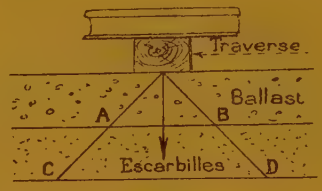


Fig. 3.

Explanation of French terms : Traverse = Sleeper. — Ballast = Ballast. — Escarbilles = Cinders.

« The increase of loads was counteracted, where it occurred by reducing the distance between the sleepers. Nevertheless, this increase operating on ground of low resistance, such as partially undermined clay, caused an exceeding of the limits of this resistance. Thus, in fact, it happened.

« The line between St-Cloud and l'Etang-la-Ville forms a characteristic example, for when the Prairie engines began to run about 1910, this disturbance of equilibrium occurred almost immediately necessitating special measures. The failure of the interposition of a layer of gravel necessitated the search for another solution. A layer of cinders a waste railway material without value, easy to procure and particularly easy to use, was inserted between the clay and the ballast.

« The interposition of a bed 0.20 m. to

0.25 m. (8 to 10 inches) was found to give the best results provided that the underlying road-bed of clay was built up to a transverse slope of 0.02 m. or better still 0.03 m. per m. (2 to 3 per cent) for the drainage of the water, and that the water, both from the road-bed beneath the cinders and from the drains, should be led into trenches. It was decided to form these of culverts on B A of smaller section.

« The experiment proved entirely successful and afforded even better results along the section between Versailles and Chartres, which was laid out about 1905-1908 where there are important clayey cuttings in a mill-stone grit formation.

« The reason for the improvement appears to lie in the fact that the load of the locomotive, instead of distributing itself over the road-bed A-B, is spread over the increased area C-D, thus distributing the load over a sufficient area of road-bed.

« This type of drainage (type A) has given satisfaction in a number of cases and must be considered the most usual. It is important that the bottom of the drainage culverts for the water should be below the level of the cinders, and that the culverts, preferably of reinforced concrete, should be kept near to (not more than 1 m. or 3 ft. 3 in. from the edge of the ballast carrying the track.

« There have been found, however, a fairly

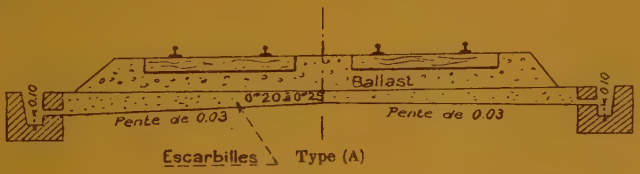


Fig. 4.

Explanation of French terms: Ballast = Ballast. — Pente de 0.03 = Slope 3 %. — Escarbilles = Cinders.

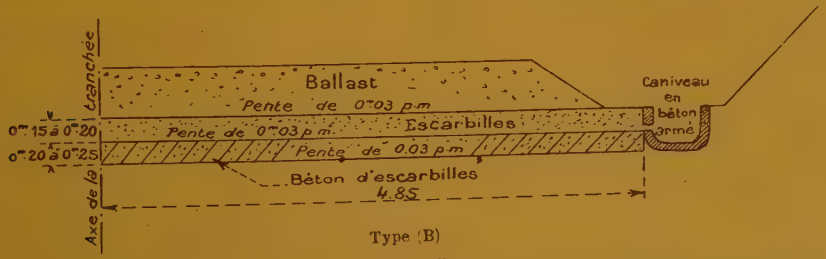


Fig. 5.

Explanation of French terms: Axe de la tranchée = Centre of the cutting. — Ballast = Ballast. — Pente de 0.03 = Slope 3 %. — Escarbilles = Cinders Béton d'escarbilles = Cinder concrete. — Caniveau en béton armé = Reinforced concrete culvert.

large number of cases in which, with the increasing weight of the traffic, drainage of this type A has not proved sufficient for ensuring the regular working of the traffic.

« We could cite as a particularly characteristic example, the Panval cutting — drained according to type A — on the Paris and Granville line.

« This occurs normally when pure grey or green loam is present and also when cutting through loam of a not so bad kind, but which has been washed away by the regular flow of water whether coming down from the hill-sides or rising from below the surface.

« It is, of course, understood that all visible springs and water coming from the sub-stratum are drained and dispersed outside the road-bed. Nevertheless, even in the driest

weather, the characteristics of loam are very different and therefore necessitate different treatments.

« The solution of the problem always depends on the same principle which consist in the increase of the area of distribution of pressure on the road-bed by means of increase in the height of the interposed mattress.

« But in practice there is a limit to the height of the cinders used as a mattress : above 0.30 m. (1 foot) thick this bed ceases to be of uniform compressibility; the variety of materials of which it is composed form a non-homogeneous mixture, and for this reason it became necessary to design another system (type B) of drainage for cuttings in loamy earth where the base is particularly wet.

« In this type, a mattress of poor concrete consisting of cinders and slag cement in the proportion of 337 or 420 lb. per cubic yard is arranged below the cinder mattress of type A. The thickness of this concrete should be at least 0.20 m. (8 inches) : — thicknesses of 0.10 m. and even 0.15 m. (4 and even 6 inches) have been broken and penetrated in places by flowing clay. The ordinary bed of cinders used as the upper mattress varies, in individual cases, from 0.15 m. to 0.20 (6 to 8 inches) in thickness.

« The conditions for drainage of water remain the same as in type A, and this also applies to the arrangement of the transverse section of the road-bed to ensure clearing the water. »

Conclusions. — « Designed thus and levelled up to the thickness determined by research on the practical trials that had been made, this type B of drainage has been found to give very satisfactory results.

« It is naturally only used, however, on very limited section of the line where justified by the local conditions.

« The cost of types A and B, which, before the war were 15 and 40 francs respectively per metre of single track (exclusive of culverts and dwarf retaining walls) has now increased to about 45 and 120 francs respectively.

« Notwithstandig this increase in cost, it is necessary to use these methods for, in default of these, loamy cuttings form special centres in the maintenance of the track at which a large amount of labour is expended uselessly, leaving an insufficiency for the regular work of general revision of the line.

« We think it should be remembered that the Orleans Railway Company and ourselves (French State formerly French Western Railway) made experiments for the solution of the problem by means of Goliath reinforced concrete slabs invented by Mr. Liébaux, chief engineer. These slabs of medium size were placed between the ballast and the clay in such a manner as to increase the bearing surface. The experiments only gave mediocre or inadequate results; reduction of expense being most readily obtained by a reduction in the area of reinforced concrete, which thereby became flatly insufficient. If the area of reinforced concrete was increased the remedy became as expensive as the type B, but the practical results were far less satisfactory. »

Paris-Lyons-Mediterranean Railway.

The *Paris-Lyons-Mediterranean Railway Company* supplies the following information :

To ensure better drainage for the water, sharp or cutting materials should not be brought into contact with the clay, with a view to reducing or preventing all interpenetration. It is for this reason that broken stone ballast should not be superimposed on the clay, and that the use of sand or unscreened gravel ballast is recommended at least for the first layer. If these precautions are found insufficient, the road-bed is drained.

1° *Method by using a layer of fine materials.*

As far as possible the work is carried out in the dry season, by diverting the track to be provided with drainage which permits of forming of the road-bed afresh. If this cannot be done, the track is laid on packing pieces of sufficient size not to penetrate the road-bed. The levelling process is carried down to the solid clay though not necessarily to the same depth over the whole of the section of track

under repair. The levelling down is done according to the requirements of the transverse sections. It is desirable that the slope of the road-bed should be at least 0.02 m. to 0.03 m. per metre (2 to 3 per cent) towards the masonry drains.

If the undisturbed clay is at too great a depth, trials are made to find the maximum depth that must be given to the ditch. This determines the level of the road-bed. If certain parts of shifting clay lie beneath this level, a pit is sunk into the undisturbed clay. The pit is afterwards rammed with a filling of dry pulverised clay watered with a grouting of lime. The upper part of this protective filling should come above the road-bed in order to be levelled up with it.

Subsequently fine material is rammed in (sand and cinders from the locomotives screened on the spot) the residue from the screening is used for filling behind the dwarf retaining walls on the outside of the bed of the track at least opposite the cross drains. The thickness of the layer of fine material should not be less than 0.10 m. (4 inches).

The ditch is constructed with invert and masonry walls on the inside. The dwarf retaining wall is pierced with cross-drains of which the bottoms are at least 0.10 m. above the invert.

This process has been carried out with success on various lines of which the lay-out, the traffic, and the equipment of the permanent way have differed greatly.

2° *Method by using longitudinal dwarf retaining walls.*

Drainage has also been executed by an entirely different procedure, and unlike anything mentioned in 1914.

In this system, a dwarf retaining wall of concrete is built on the side of the track which shows abnormal movement just under the ends of the sleepers. The drawing shows the consolidation of a double track line where movement was found to occur both as regards the six-foot way and the four-foot way.

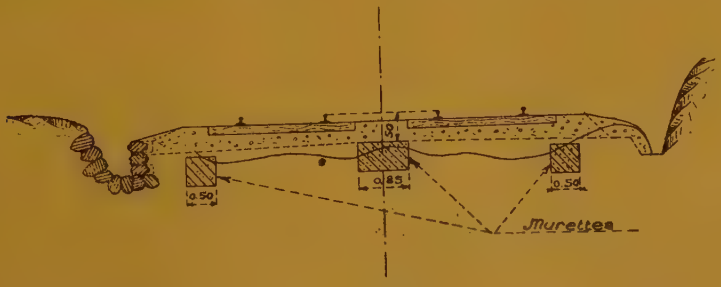


Fig. 6.

Explanation of French terms: Murettes = Dwarf walls.

The top part of the dwarf retaining wall is brought down to the normal level of the road-bed, about 0.50 m. (1 ft. 8 in.) below the rail next to the six-foot way and about 0.60 m. (2 feet) below the outer rail. It should be established on the firm clay not rammed down, and built into it in such a manner as to ensure stability. The dwarf retaining walls under the outer rails are 0.50 m. (1 ft. 8 in.) in width, that of the six-foot way depending on the free space between the sleepers, that is about 0.85 m. (2 ft. 9 1/2 in.). The clay is not touched below the sleepers, but it is allowed to remain in the position it has taken due to the deformation.

The concrete of the dwarf retaining walls is made from unscreened gravel ballast, if such is used in the district, or, if not, from locomotive cinders. The proportions used may be 337 lb. of hydraulic lime per cubic yard of unscreened material.

This system gave rise at first to some objections due to the principle involved. But in such cases experience alone can enable the

value of any method of consolidation to be appreciated at its proper value. One can now judge of the results obtained. The system was applied on several lines, forming a total length of 7 827 yards of single dwarf retaining wall distributed as follows :

5 376 yards single wall;
922 yards, double wall;
202 yards, triple wall.

The length of the experiments dates back about 34 years for the oldest of these cuttings, among which it is reckoned that six have been treated as far back as 30 years ago, nine 25 years ago and six 20 years ago.

The track is perfectly stable. The trackmen whe knew the lines before the construction of the first dwarf retaining walls have watched the results and they testify unanimously to the success of the method.

The system is very simple in application and does not call for any special precautions or care. The dwarf retaining walls on those lines on which they were adopted were built by the plate-layers.

The system has the advantage of limiting the work to the unstable portion of the track, and, in consequence, of proportioning as nearly as possible the outlay to the end in view. If one of the outside rails moves, a dwarf retaining wall is built on the outer side corresponding to the spot at which the movement occurred. If one of the inner rails next to the six-foot way should move, a dwarf retaining wall is similarly constructed under the six-foot way of the necessary length. If, at a later date further movement occurs, the dwarf retaining walls are prolonged as far as is necessary.

Thus, as said above, it is not necessary in this method to rectify the sunken surface of the road-bed between the dwarf retaining walls and it is left in the condition in which it was found.

Investigations have shown that this surface has generally been found to be below the level of the dwarf retaining walls as shown in the diagram.

Investigations have also shown that the ballast of unscreened gravel had proved suitable for packing, but that the ballast of broken stone on the contrary had been penetrated by clayey water.

For discharging the water contained between the dwarf retaining walls it was attempted to devise an earthenware pipe drain for draining it. But on account of the irregularity of the clay bed it was found that the water remained just the same at the points so treated.

In every case, however, whether discharge pipes have been employed or not, the system has afforded good results.

Under these conditions it can be concluded from experience extending over a period of thirty-four years, that the stability of the track in clayey cuttings, similar to those which have been dealt with, can be efficiently ensured by building dwarf retaining walls of concrete.

The lay-out of the line between Louhans and St-Amour where the construction of dwarf retaining walls has been carried out on a large scale, has the following characteristics :

Maximum gradient 0.010 m. per mile (1 per cent).
Minimum radius of the curves 50 chains.

Since the construction of the first dwarf retaining walls the equipment of the track. the amount of traffic, and the wheel-load has varied considerably. It has however in no wise affected or caused deformation of the road-bed.

Orleans Railway Company.

The *Orleans Company* had described the work that it has found necessary to carry out since the war.

In certain damp cuttings longitudinal collecting drains have been used in conjunction with transverse drains, but this work is of too recent an origin to permit of judging its results.

In addition, since the termination of hostilities, this Company has found it necessary to prevent the track from shifting at certain particularly clayey places by means of sleeper blocks. The rail 11 m. (36 ft. 1 in.) long thus

rests on twenty-one supporting surfaces, fourteen on sleepers and seven on sleeper blocks.

The conclusions formed by the Company at the present time are as follows :

The slabs in reinforced concrete known as « Plaques Goliath » have not given satisfactory results. Sometimes the slabs have become embedded by tilting, many have become broken into large and even small fragments under the load of the trains. The continuous paving of thin concrete is preferable to the « Goliath » slabs.

In the opinion of the company the best procedure is :

1° Where the line has yet to be constructed the road-bed should be dropped to such a level that the thickness of the mattress of ballast or cinders between the sleepers and the surface of the clay shall be sufficient to prevent the movement of this clay. If this is inadequate to reduce the pressure on the layer of clay sufficiently, the number of sleepers may be increased. In this respect prevention is much easier than cure;

2° Where the line is already in existence and wherever such a course is possible, the clay should be cut down sufficiently to come below the lower parts of the wave curve that is always taken by clay road-beds, and at the same time the bottom of the ditches should be kept at a lower level than that of the clay road-bed.

French Midi Railway Company.

The *French Midi Railway Company* have replied to the inquiry in relation to their double track line from.

Bordeaux to Cette. — The line is equipped with rails 11 m. (36 ft. 1 in.) long weighing 38 kgr. per m. (76.60 lb. per yard) laid on fifteen sleepers.

The heavy locomotives running have a weight of 18 tons per axle with a distance of 2.00 m. and 2.10 m. (6 ft. 6 3/4 in. and 6 ft. 10 3/4 in.) between centres of the axles.

The maximum speed of passenger trains is 52.8 miles per hour, that of goods trains 24.8 miles per hour, and the greatest speed attained on the straight is 74.6 miles per hour.

The annual tonnage is about 6 000 000 tons in each direction.

* * *

Cuttings in clayey districts are to be found in the line above mentionned, but neither deformations of the road-bed, nor winding deformations of the track, nor displacements of the outer rail have been noticed. Nevertheless some of the sleepers have been found to rock and to throw up mud at the ends.

On embankments no increasing penetration of the road-bed by the ballast has occurred.

Operations to deal with rising clay have been carried out. The bed of clay has been cut down by 0.20 m. (8 inches) in height and a mattress of slag of an equal thickness has been substituted for it.

The outlet of water has been ensured by transverse and longitudinal drains with a collecting duct at a sufficient depth below the ditch.

No experiments have been made either with reinforced concrete slabs or with casings of ordinary concrete.

The conclusions of the French Midi Railway Company are as follows :

When the road-bed has to be constructed by filling up on embankments, the embankment should be built up of good soil of a non-clayey variety and care taken that the base of the embankment should not be undermined by infiltration of water.

When the road-bed has to be made in cuttings on a clayey soil, the road-bed should be cut down to 0.40 m. (1 ft. 4 in.) below the lower level of the sleepers, and a bed 0.20 m. (8 inches) thick of sand or cinders should be added. The outlet of water should be assured by means of sufficiently deep ditches.

On embankments as in cuttings the road-bed should have an inclination of 0.03 m. per metre (3 per cent) from the centre of the railway; its width should be 9.50 m. (31 ft. 2 in.), not including the ditches, for a double track

line and 6.00 m. (19 ft. 8 in.) for a single track line.

The thickness of the ballast under the sleepers should be 0.20 m. (8 inches) and the ballast should be made even with the level of the top of the sleepers so that their upper surfaces are exposed.

Paris Ceinture Railway.

The lines are double tracks with heavy gradients, the maximum being 15 mm. per metre and 11 mm. per metre (1.5 and 1.1 per cent) where the clay has been cut down.

They are run over by the heavy locomotives of all the French systems hauling passenger trains at slow speeds of 31 to 37.3 miles per hour, and hauling goods trains (of 40 trucks) at 15.5 to 24.8 miles per hour.

The maximum speeds attained on the straight are 49.7 miles per hour.

The annual tonnage in each direction is :

Contra-clockwise 11 500 000 tons;
Clockwise 13 240 000 tons.

The track is constituted either of Vignoles rails weighing 37.30 kgr. per metre (75.20 lb. per yard) in lengths of 6, 12 and 18 m. (19 ft. 8 in., 39 ft. 4 in. and 59 feet) or of Vignoles rail of the type used on the French Eastern Railway of 46 kgr. per metre (92.73 lb. per yard) 18 m. (59 feet) long.

The rails 6 m. (19 ft. 8 in.) in length are placed on 7 or 8 sleepers according to circumstances, those of 12 m. (39 ft. 4 in.) on 18 sleepers and those of 18 m. (59 feet) on 27 sleepers.

The ballast is usually of siliceous stone having a minimum thickness of 0.22 m. or 0.23 m. (8 3/4 or 9 inches) under the sleepers.

Facts observed. — These are a verification of those expounded at the conference in 1914 by the different railways that were asked for information.

Operations carried out. — They are : The levelling down of the clay to a thickness of 0.30 m. (1 foot) the arrangement of longitudinal ducts and transverse drains; of a mattress of slag, and of a layer of old ballast over a thin bed of sand (rabbit warren sand); and the use of « plaques Goliath ».

Different schemes were chosen in the course of the operations, in particular those shown in the figures 7 to 9.

Results obtained. — In the dry cuttings a layer of slag stood well.

In a damp cutting the slag mattress was found to be inefficient and the drains inoperative.

By contrast, in other damp cuttings satisfactory results were obtained by use of a mattress of old ballast superimposed on a bed of rabbit warren sand.

The rabbit warren sand under pressure does not give way but stops the clay from rising and prevents the damp from penetrating to the ballast.

It is realised that a thicker layer of the warren sand would be desirable, but this would be more expensive than the slag, of which the railway systems always have an abundant supply.

If the *Ceinture Railway Company* had at its disposal sufficient quantities of the rabbit warren sand, it would not hesitate to use such a sand in a thick underlying layer even in cuttings where the road-bed is dry.

Convincing results were not obtained from the « Plaques Goliath » .

Conclusions. — For the construction of new lines, intended for heavy and rapid traffic, it is desirable to lay a track of heavy material with close-spaced sleepers on a sound road-bed.

Rails of 46 kgr. per m. (92.73 lb. per yard) give good results from the point of view of wear of the rails themselves and the maintenance of the track.

For drawing off the water, the slope of the road-bed towards the ditches might be carried to 0.03 m. per m. (3 per cent) or even more to give more rapid flow and to reduce the penetration of water into the road-bed.

The ditches, whether of earth or masonry, should be large in order that they may not get rapidly choked up, and also that they may be more easily cleaned; the size of the invert

Removal of clay carried out in 1902.

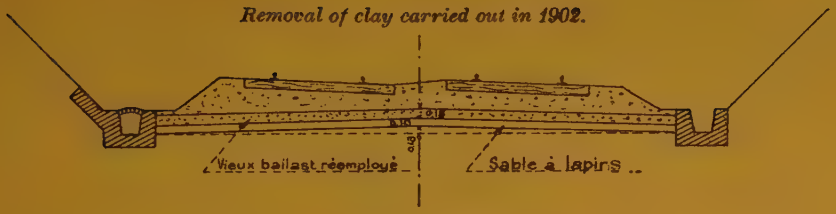
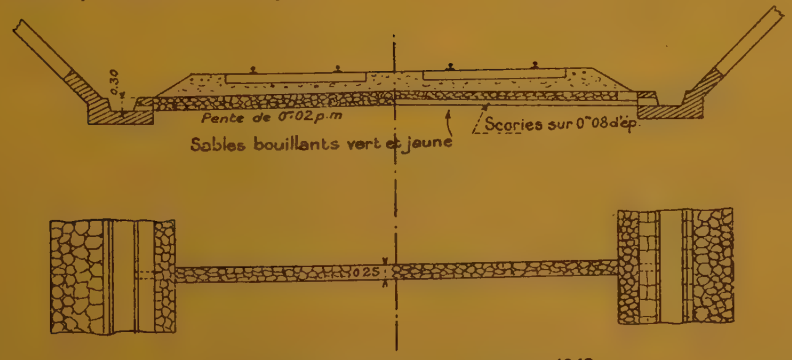


Fig. 7.

Removal of clay carried out in 1918.

Fig. 8.

Drain of stones laid on slag. *Drain of stones laid on slag.*



Drainage carried out in January 1919.

Fig. 9.

Explanation of French terms: Vieux ballast reemployé = Old ballast used over again. — Sable à lapins = Rabbit warren sand. — Drain longitudinal = Longitudinal drain. — Caillou = Stones. — Scories 0.30 = Slag 0.30 m. (1 foot) thick. — Drain en pierres posées sur glaise = Drain of stones laid on loam. — Scories sur 0.08 d'ép. = Slag 0.08 m. (3 1/8 inches) thick. — Sables bouillants vert et jaune = Green and yellow quicksand.

should not be less than 0.40 m. to 0.45 m. (1 ft. 4 in. to 1 ft. 6 in.), the depth should go at least 0.10 m. (4 inches) below the level of the road-bed (in places where the clay has been levelled down it should go at least 0.10 m. below the level to which the clay has been brought); the height of the dwarf retaining walls depends on the depth of the trench and on the level of the base of the bank of ballast to be supported.

Numerous crosswise drains should be carried through the dwarf retaining walls at the side of the track; they should be high and not too wide (height 0.20 m. [8 inches] and width 0.06 m. [2 3/8 inches]) and start at 0.10 m. (4 inches) above the invert, spaced at 2 m. (6 ft. 6 in.) apart at the maximum in damp sections and 5 m. (16 ft. 5 in.) apart in ordinary section.

The best ballast for preserving and draining the tracks consists of slag or broken siliceous stone.

Particularly where the road-bed is built up of several layers of earthwork, care should be taken to exclude from the embankment any loamy earth or marl; chalk, even when free from clay, should not be used for embankments more than can be helped.

French Northern Railway Company.

The *French Northern Railway Company* gave, at the 1914 conference, some interesting information on the wear of slag mattresses of considerable thickness laid in place after the clay had been levelled down, and also on the use of concrete casings of broken slag and slag cement.

The mattress of fine slag used in particular on the line from *Busigny to Hirson* has a thickness of 0.40 m. (1 ft. 4 in.) under the ballast of the superstructure, and is completed by a lateral drain of 30 cm. (1 foot) in diameter replacing the ditch. It gave satisfactory results during the first seven or eight years. After that, little by little, the clay penetrated the mattress; the experiment dates to 1905.

At the present time the mattress is contaminated throughout its thickness, but the ballast is still clean, and there has been no perceptible deformation of the track; the drains are still working satisfactorily.

The track here is equipped with rails 8 m. (26 ft. 3 in.) long, weighing 30 kgr. per m. (60.48 lb. per yard) resting on 11 sleepers only, while the ballast is formed of broken slag to a thickness of 0.23 m. (9 inches) beneath the sleepers.

The second experiment, taken up at the 1914 conference, is that of constructing a casing of concrete of slag cement and broken slag in proportions prepared dry beforehand at the quarry to facilitate the operations on the spot. A central masonry drain serves to discharge the water that has got through the ballast.

Begun in 1913, in the great cutting of *Terlincthun*, on the line from *Paris to Calais*, between *Boulogne* and *Wimereux*, the operations have not been continued since 1914.

The ground at this cutting is very treacherous, of blue clay with many springs.

The track is equipped with rails 12 m. (39 ft. 4 in.) long, weighing 45 kgr. per m. (90.71 lb. per yard) carried on 16 sleepers. The ballast is of broken stone from the « Vallée Heureuse », and has a thickness of 0.20 to 0.25 m. (8 to 10 inches) under the sleepers.

The line has a gradient of 8 mm. per metre (8 per mil) and a curve of 50 chains radius.

During the war there was considerable traffic, and the casing did not wear as well as might have been hoped. It became distorted and broken.

This failure is due in a measure to the composition and construction of the concrete both of which left much to be desired, and partly, very probably, to the fact that the casing was constructed with its upper level too near (about 0.25 m. [10 inches]) to the underside of the sleepers.

In spite of hostilities repair work on the road-bed had to be put in hand quickly at certain points of the same cutting of *Terlincthun* outside that provided with the casing.

It was in this way that a mattress of dune sand of 0.20 to 0.25 m. (8 to 10 inches) thick was tried under the usual bed of ballast made from cinders from the locomotives in default of other material. The superstructure was at the same time reinforced by the addition of

sleeper blocks bringing the number of supports up to 21 per 12 metre (39 ft. 4 in.) rail length.

This work was carried out in 1917; it has proved entirely satisfactory up to the present time. There is no sign of undulating movement in the road-bed; the substrata and the pure sand are held laterally by masonry ditches. Since it has been laid, the bed of fine sand has absorbed by capillarity, the water from the moist clay which has become quickly dried up and has since retained its proper form without spreading.

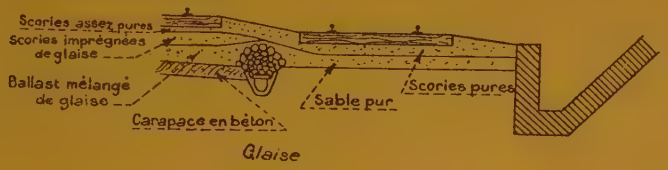


Fig. 10.

Explanation of French terms: Scories assez pures = Fairly pure slag. — Scories imprégnées de glaise = Slag mixed with loam. — Ballast mélangé de glaise = Ballast mixed with loam. — Carapace en béton = Concrete casing. — Glaise = Loam. — Sable pur = Unmixed sand. — Scories pures = Unmixed slag.

At the end of four years the clay has not yet penetrated the fined sand. This experiment appears to be of particular interest.

Another interesting piece of work is the concrete casing constructed in the cutting of the « Lion d'Or » near *Lille*, where the road-bed common to the *Lille-Calais* and *Lille-Roubaix-Tourcoing* and *Mouscron* lines is established on very damp sandy loam.

The track is equipped with rails 18 m. (59 feet) long weighing 45 kgr. per m. (90.71 lb. per yard) and resting on 25 sleepers.

The traffic is very heavy.

The annual tonnage is about 6 200 000 tons on the *Calais-Mouscron* routes as well as on the *Lille* route. All types of heavy locomotives are run.

The casing was constructed as shown in the following diagram with longitudinal drains collecting and discharging the water that had penetrated the superstructure.

A recent examination has shown that the

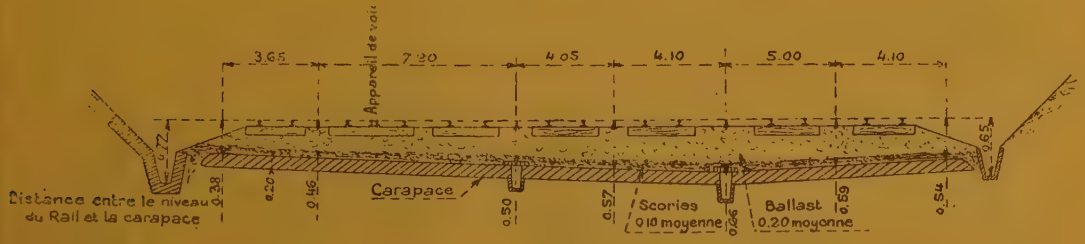


Fig. 11.

Explanation of French terms: Appareil de la voie = Track appliances. — Distance entre le niveau du rail et la carapace = Height of rail-level above the casing. — Carapace = Casing. — Scories 0.10 moyenne = Slag about 0.10 m. (4 inches) thick. — Ballast 0.20 moyenne = Ballast about 0.20 m. (8 inches) thick.

casing has behaved quite satisfactorily and is practically every-where intact although it was not constructed of hard concrete.

Conclusions. — The *French Northern Railway Company* thinks that the levelling down of clay road-beds where the track has been in use should be carried out as follows :

In damp cuttings where sandy loam occurs,

the mattress of fine slag 0.30 to 0.40 m. (1 foot to 1 ft. 4 in.) in thickness replacing an equal layer of clay and placed below the usual ballast about 0.20 m. (8 inches) under the sleepers should be sufficient to ensure that no deformation of track will occur even under the heaviest loads. The slag should moreover bear laterally against the dwarf masonry retaining walls forming the sides of ditches of sufficient depth.

In very damp cuttings, and in the case of blue clay, the slag should be replaced by fine sand, dune or rabbit warren sand, between lateral dwarf retaining walls.

Finally, in very unstable road-beds with numerous springs, recourse might be made to the casing of concrete, but this is the extreme case.

The concrete should be made with care, using cement as an agglomerating agent and lime should not be used.

The operations should never be carried out under traffic, and the track above the casing should not be again used until sufficient time has elapsed for the concrete to have hardened enough to support the rolling loads safely.

The casing should be constructed at such depth as to allow of a mattress of slag to be superimposed to a depth of 0.15 m. to 0.20 m. (6 to 8 inches) below the normal ballast.

In the construction of new lines mattresses of slag or fine sand between dwarf retaining walls or masonry ditches, or where it is found necessary, a concrete casing, according to the consistence of the road-bed, should be arranged for in the original work of construction.

Alsace and Lorraine Railways.

The Alsace and Lorraine Railways have replied fully to the questionnaire, as far as concerns the double track lines of *Thionville-Voelkling*, *Thionville-Luxembourg* and *Luxembourg-Kleinbettinghen*.

The following is a summary of their reply :

Maximum gradients	*Thionville-Voelkling*	1.11 %
	Thionville-Luxembourg	1.33 %
	Luxembourg-Kleinbettinghen	9 %
Minimum radius of curves	*Thionville-Voelkling*	15 chains.
	Thionville-Luxembourg	20 —
	Luxembourg-Kleinbettinghen	15 —
Maximum speed on the straight.	*Thionville-Voelkling* (Slow passenger trains)	37 miles per hour.
	Thionville-Luxembourg (Express)	53 — —
	Luxembourg-Kleinbettinghen (Express)	53 — —
	Goods Trains	18 1/2 — —
Maximum speeds on curves of small radius or at special places.	*Thionville-Voelkling* (Curves of 15 chains)	37 miles per hour.
	Thionville-Voelkling (Turn outs on a curve)	28 — —
	Thionville-Luxembourg (Curves of 20 chains)	46 — —
	Luxembourg-Kleinbettinghen (Curves of 15 chains)	40 — —
Annual tonnage carried.	*Thionville-Voelkling*	15 400 000 t.
	Voelkling-Thionville	17 600 000 t.
	Thionville-Luxembourg	13 500 000 t.
	Luxembourg-Thionville	13 100 000 t.
	Luxembourg-Kleinbettinghen	5 100 000 t.
	Kleinbettinghen-Luxembourg	4 900 000 t.
Number of trains in each direction.	*Thionville-Voelkling* : 2 800 to 3 900 passenger, 3 960 to 5 360 goods (In each direction).	
	Thionville-Luxembourg : 4 600 to 7 970 passenger, 4 150 to 5 750 goods (In each direction).	

Number of trains in each direction. { *Thionville-Kleinbettinghen :* 4 380 passenger, 3 240 goods. *Kleinbettinghen-Luxembourg :* 4 380 passenger, 2 950 goods.

Average number of pairs of wheels in a train. { *Thionville-Voelkling :* 26 to 28 passenger, 70 to 76 goods. *Thionville-Luxembourg :* 40 to 46 passenger, 70 to 90 goods. *Luxembourg-Kleinbettinghen :* 34 passenger, 90 to 96 goods.

Extremes of temperature during the year . . . . . + 95° F. to — 4° F.

Mean rainfall . . . . . 26 3/4 inches per year.

Weight of heavy locomotives : Maximum axle load . . . . . { 15.75 English tons (Class S. 12). 16.80 — — (Class S. 10). 16.88 — — (Class G. 81). 16.78 — — (Class G. 121).

* * *

Works carried out. — The first devices used have consisted in the establishment of transverse stone drains, in conjunction with other longitudinal stone drains in certain cases.

These measures have proved to be insufficient in the cuttings in clay. There were therefore constructed strong masonry walls at the foot of the slope along the side of the line, between which were made masonry drains to receive the water running from the outlets in the walls.

The outlet holes in the walls were not long in becoming obstructed, and then the water remained on the road-bed, causing, the contamination of the ballast; the road-bed became worse than it had been before the construction of the walls and masonry ditches.

Some new experiments had to be tried.

Ten years ago the first experiment was carried out on the *Thionville-Luxembourg* line in the cutting situated near *Zoufftgen.*

Under the ordinary ballast of the track was placed a layer of powdered slag 30 cm. (1 foot) thick, extending over the whole road-bed up to the ditches, the depth of which was increased in consequence. After a time this powder is acted upon by the damp and acquires the consistency and hardness of concrete, preventing any further infiltration of the water.

It was feared that the pavement thus obtained would crack at the rail joints, but this defect has not manifested itself, and the rail bed has since remained in a good condition.

* * *

Another long, deep and damp cutting on the *Luxembourg to Kleinbettinghen* line has been drained by means of a thick bed of quarry sand, beneath the broken slag ballast.

A central drain has been made in the middle of the six-foot way, the original masonry drains being no longer able to drain away the water.

Although the work of drainage has not been able to be completed for more than one road only, in consequence of the war, a dry road-bed has already been obtained.

The *Thionville to Luxembourg* line, where the first drainage works have been undertaken, is laid with rails of 15 metres (49 feet) in length and weighing 45 kgr. per m. (90.71 lb. per yard), carried on 23 hard-wood sleepers. That from *Luxembourg to Kleinbettinghen* is laid with rails 12 m. (39 ft. 4 in.) long, weighing 38 kgr. per m. (76.60 lb. per yard), carried on 19 sleepers.

* * *

Finally, an arrangement almost the same as that on the *Luxembourg to Kleinbettinghen* line was constructed about ten years ago at Metzerwisse Station on the *Thionville to Voelkling* line. The results have always been quite satisfactory.

The main drain placed in the centre of the six-foot way is formed of a concrete pipe 1 ft. 7 1/2 in. in diameter and with the upper

part perforated with holes to drain off the water. At intervals the collecting pipe opens into sump holes to collect the solid matter.

On the road-bed suitably levelled is placed a layer of rammed cinders 30 cm. (1 foot) thick, on which rests the broken slag ballast also 30 centimetres thick under the sleepers.

The quarry sand is, however, surely preferable to the cinders.

The *Thionville to Voelkling* line in *Metzerwisse* Station is laid with rails 15 metres (49 feet) long, weighing 41 kgr. per m. (82.65 lb. per yard), carried on 22 hard-wood sleepers.

General remarks. — From the results of experiments made on the *Alsace and Lorraine Railways* it has been concluded that a spacing of 2 ft. 2 3/8 in. between the sleepers and a layer of ballast 30 cm. (1 foot) thick beneath the sleepers is sufficient to avoid deformations of the road-bed for the loads and speeds in actual use.

The road-bed on clayey soil has great resistance when dry, but soon becomes viscous under the action of rain water and this demands the application of measures of complete protection against water by the construction of arrangements which will assure drainage so rapid that the water cannot soften the road-bed by lying on it.

The static weight per wheel being 8 000 kgr. (15.7 t. per axle), the distance from centre to centre of the sleepers being supposed 80 cm. (2 ft. 7 1/2 in.), and the dimensions of the wooden sleepers being 26×16 cm. (10 1/4×6 1/4 inches) with a length of 2 m. 7 (8 ft. 10 in.), the pressure on the ballast is about 1.2 kgr. per cm² (17 lb. per square inch) beneath the rails, 1.3 kgr. per cm² (18 1/2 lb. per square inch) at the centre of the sleepers (in the middle of the track) and 1.1 kgr. per cm² (15 1/2 lb. per square inch) at the ends of the sleepers.

The forces exerted on the ballast have been somewhat reduced by increasing the number of sleepers, which has been carried out on the principal main lines to improve the stability of the track. Any further increase, however, in the number of sleepers is not possible in view of the difficulty which would be experienced in packing the ballast. On the other hand, the ballast has a far greater influence on the efficient distribution of pressure. The use of good quality broken stone, in the place of gravel, increases the resistance of the road-bed as well as that of the track sufficiently to leave room for no misgivings, that the dynamic forces to which the road is subjected will be too great, even in the event of a new increase in the weights of rolling stock and in the speed of trains, provided always that the road-bed is well drained and that the layer of ballast is of sufficient thickness (30 cm. [1 foot]).

[385 .113 (.494) & 621 .33 (.494)]

Report of the Swiss Federal Council to the Federal assembly on the report of the Federal Railways Commission of the National Council the financial situation of the Federal Railways and their electrification programme; and also on the Gelpke report concerning the results obtained by the adoption of electric traction. (Dated the 7 June, 1921).

On the 18 January 1921, two reports were submitted to the Federal Council, one by the Federal Railways Commission of the National Council, the other by Mr. Gelpke, National Councillor.

The first is in the following terms:

« The Federal Council is invited to present, at an early date, to the Federal Chambers a report :

« 1° On the financial situation of the Federal Railways, and the measures to be taken to re-establish balance in the profit and loss account and to meet the existing deficit;

« 2° On the electrification programme of the Federal Railways, and the financial result of the replacement of steam traction by electric traction. »

The second reads as follows :

« The Federal Council is invited to present to the Chamber a memorandum concerning the results of electric traction on the 90 km. (56 miles) section from Erstfeld to Biaca, with a comparative table of the cost of electric and steam traction respectively on the basis of the following prices per ton of coal.

« *a*) 150 fr.; *b*) 110 fr.; *c*) 70 fr. (1). »

The two reports have a certain relation one to the other, and were discussed together by the National Council; therefore it is convenient to deal with both in a single report. After having consulted the board of management of the Federal Railways, we have the honour to reply to the invitation extended to us, as follows :

A. — *Report of the Federal Railway Commission of the National Council.*

1. — Financial situation of the Federal Railways and reestablishment of equilibrium in the profit and loss account : measures to be taken to meet the existing deficit.

In their report of the 12 March 1920, the board of management of the Federal Railways and the permanent commission of the administrative council gave to the latter body detailed information on the financial situation of the railways and the measures to be taken to meet the deficit. This report, which was presented at the same time to the members of the Federal Chambers, contained an estimate of receipts for the years 1920 to 1924; it foresees a gradual diminution of the deficit on the annual profit and loss account. Naturally this estimate is quite approximate, for it was not possible at that time to foresee, even for a short time, what would be the general economic development on which ultimately depends the state of the re-

ceipts and expenditure of the Federal Railways.

It is already evident that the figures of the said report are no longer in accordance with the actual facts, for since then the economic situation has changed in a very unexpected manner, not only in Switzerland, but in the whole world.

The changes which have taken place have had both a favourable and an adverse effect on the financial situation of the railways.

We would remark, however, that even to-day it is not possible to find any stable basis of discussion, and that therefore the figures which we give may eventually require modification according to circumstances.

Working receipts.

The *traffic receipts* for 1920 are appreciably higher than those anticipated in the report of the 12 March 1920; the cause for this was a greater increase of traffic than had been counted upon, and the increase of rates and fares introduced on the 1 August 1920. But the crisis through which for some months we have been passing has resulted in a diminution in traffic, so that it is no longer possible to count on the annual increase of 5 % originally quoted for passenger traffic, and 4 % for goods traffic. The Federal Railways, therefore, do not rely in the estimates on any traffic increase in 1921; they merely hope for higher receipts as a result of the last increase of rates and fares, which only affected the last five months of 1920, whereas it will affect the whole of the year 1921. For the following years they count on a moderate increase of traffic, thus :

Year.	Passenger traffic.	Passenger traffic.
—	—	—
1922	2 %	1 %
1923	3 %	2 %
1924	4 %	3 %

On the other hand, the Federal Railways consider that they may estimate the miscellaneous receipts at a somewhat higher figure than that suggested in their report of 1920, because the leases, fixed charges and rents have increased in the meantime and their is a tendency towards other increases in the coming years.

The revised estimates of working receipts are consequently as follows :

YEAR		Traffic receipts, in francs.	Miscellaneous receipts, in francs.	Total working receipts, in francs.
1920	According to accounts in round figures.	381 000 000	13 000 000	394 000 000
	According to the report of the 12 March 1920.	(343 000 000)	(10 700 000)	(353 700 000)
1921	...	401 000 000	13 100 000	414 100 000
1922	...	406 200 000	13 200 000	419 400 000
1923	...	415 600 000	13 300 000	428 900 000
1924	...	429 400 000	13 400 000	442 800 000

We do not consider that these figures are excessive. Although the present crisis may check the increase in receipts to a greater extent than is now antici-

pated, it is probable that once the crisis is passed the development of traffic will be considerably greater than contemplated in the report.

Working expenses.

In view of the uncertainty as to the future, the working expenses, like the receipts, can only be estimated approximately. In 1920 they amounted to 346 000 000 fr., only exceeding, therefore, by very little the total of 345 600 000 fr. estimated in the report.

The findings of the report in respect of the years 1921-1924 will consequently require the following modifications, as far as one can foresee future conditions :

1. — The revision which the « Federal Law on salaries and adjustment of wages » is at present undergoing, will result in increased expenditure unless it is accompanied by a considerable lowering of prices. Taking as a basis the Bill drawn up by the Federal Department of Finance and the total personnel as at the 1 April 1921, there results a new charge of 5 000 000 fr. per annum. This increase will probably begin to burden the budget from the year 1922.

There is no anticipation of new commitments for the succeeding years because the majority of the employees will have reached their maximum wages, and future increases will no doubt be counterbalanced by the process of elimination which will naturally take place in the personnel.

2. — The 1921 budget includes a sum of 4 400 000 fr. in respect of « cost-of-living bonuses » to pensioners. These bonuses will disappear in the future, from the heading of expenses of working, if the pensions and benevolent department has to meet these allowances. It is true, that the result will be an increased deficit for the pensions and benevolent fund, interest and redemption charges in respect of which will of course fall on the Federal Railways.

3. — As a consequence of the strict application of the new law regarding hours of labour, the 1921 budget anticipates increased expenditure on « salaries and wages ». But, thanks to the reduction in the number of staff, which the commission of enquiry into the working conditions and personnel considers may be effected in the stations, the expenditure on employees' wages will not increase to the extent calculated before the Act regarding hours of labour comes into force, even though the present reduced traffic should again increase considerably. It is not yet possible to give an exact idea of the extent of the economy which will result from the measures in question. By putting into practice the principles laid down by the Commission, the district boards themselves have already effected certain reductions; but, in view of the general lack of employment which prevails at the moment, the superfluous staff cannot be dismissed at very short notice; the reduction will take place generally by the process of natural elimination. It is, however, already certain that as a result of the new reforms and the diminution of traffic, it will not only be possible to apply the new law as regards hours of labour in its entirety in 1921 (granting of more rest days and holidays, diminution of merely stand-by calls and prolongation of night rest), but without increasing the personnel; it will also be possible to effect a further reduction in personnel. Thus, by a better organisation of the service in stations and depots, there will be no increase in expenditure on the working staff as anticipated in the report of the 12 March 1920. The estimated difference must therefore be allowed for in the new estimate. The diminution in the expenses which may be expected from the above reforms is estimated by the Federal Railways at 7 million fr. in 1921, 8 millions in 1922 and 9 millions for the years 1923 and 1924.

4. — An important modification will be effected in the payments to be made by the administration of the Federal Railways to the pensions and benevolent fund. The whole of the original increased cost-of-living bonuses have been included in the fund as from the 1 October 1920, and regular employees on the line and in the workshops will probably be admitted as members in the fund retrospectively for the 1 January 1921. The budget of 1921 has taken into account the liabilities due from the pension fund in respect of the original bonuses and of increased wages dating from the 1 April 1921, but not in respect of admission to the fund of regular workmen. The statutory contribution of five-twelfths of the total original bonuses was first estimated at 25 000 000 fr. and a first annuity charge of 3 237 600 fr. was included under this heading in the budget with the object of spreading the redemption of this additional expenditure over a period of ten years, with a rate of interest of 5 %. The total contribution of the Federal Railways to the pensions and benevolent fund was thus placed at 14 580 000 fr. for 1921.

The new statutes which are being drawn up for the pensions and benevolent fund will considerably modify the total of the contributions. According to the proposals, instead of four-twelfths of the increased grants resulting from the counting of the complete original bonuses, the personnel will only have to pay a small part of this increase. The contributions of the administrations are therefore correspondingly reduced. They will amount to only 8 400 000 fr. instead of 25 000 000 fr. It must, however, be remarked in this connection, as in the case of the abolition of the cost-of-living bonuses to pensioners, that this reduction of the contribution will entail an increase of the deficit of the fund, which ultimately will have to be met by the administration of the Federal Railways.

The admission of regular workmen into the fund, contemplated by the new statutes, will also occasion a large increase of the deficit. In order to reduce it, the intention is to fix at 5 % the rate of interest on the balance in the account instead of 3 1/2 % as at present. The necessary condition of this measure would be that the administration of the Federal Railways should guarantee this interest to the fund, that it should take responsibility therefore for the deficit if the securities on which the reserve is placed did not reach this rate. Further, it has been decided that, in conformity with the statutes of the State insurance fund, the ordinary contribution of the Federal Railways, amounting to 7 % of the wages of the personnel, should be increased, as from 1924, by 1 % per annum, until it reaches 11 %.

It is not possible up to the present to say to what sum the adverse balance of the pension fund will amount under the state of things instituted by the new statutes. In this connection it will be necessary to make exact calculations after the adoption of these statutes. For the present the Federal Railways anticipate that they will pay annually, and in the usual way, 1 500 000 fr. in respect of interest and redemption of the deficit. When the new amount has been fixed, it will be necessary to arrange for its redemption, *i. e.*, of the deficit, within a determined period of time.

As will be seen from the above, the contributions of the Federal Railways to the pensions and benevolent fund constitute a heavy charge on the working account. Still greater sacrifices will be necessary in the forthcoming years by reason of the conditions resulting from the better pensions contemplated for the staff. This state of affairs has given rise to proposals designed to reduce the cost to the Federal Railways, either by partially deferring their contributions to the fund until the present crisis has been passed, or by continuing to pay

out instead of putting to reserve. We do not feel able to support these proposals, for the future payments of the fund would not be modified thereby; the only result would be an immediate relief at the expense of the future; the Federal Railways cannot possibly derive any benefit from an excessive increase of future commitments.

As regard the benevolent funds of the private Railways, the system of reserves must be maintained in every case, because it is only through them that the employees can be sure of obtaining their pensions. The pensions and benevolent fund of the Federal Railways being administered, as in the case of private railways, as a special and independent branch of the undertaking, it is advisable that the same system should operate. This fund should serve as a model to the private undertakings.

The important reserve which accumulates gradually in the pension fund of the federal Railways cannot moreover be considered as dormant capital. It is permissible for the Federal Railways to employ the available monies of the fund in constructive work, against the deposit of securities, as indeed is already done. As long as the reserves increase, which will be the case for a number of years to come, the Federal Railways will find in the annual increase a very welcome financial aid in the electrification of their. lines. This advantage can naturally only be of value when financial equilibrium has been restored on the Federal Railways and when contributions to the pensions and benevolent fund can be made without increasing the debit balance.

5. — The *Reduction in the cost of fuel* which has taken place recently will lead to a considerable reduction in the cost of motive power. This economy will, however, only be felt gradually, for large stocks of coal still exist (about 700 000 t.), bought as a precautionary measure, but bought at high prices. In 1920 coal cost on the average 175 fr. per t.; as regards the immediate future, the Federal Railways reckon on an average price of 150 fr. in 1921 (budget, 200 fr.), 110 fr. in 1922, 90 fr. in 1923 and 80 fr. in 1924.

On the basis of these prices the following expenditure is calculated for the mileage to be taken into consideration, assuming that as from 1921 the average coal consumption is 18.5 kgr. per km. (5/8 mile) per locomotive.

YEAR.	Steam locomotive kilometres.	Electric locomotive kilometres.	Expenditure on fuel.	Cost of electric power.	Total expenditure.
1920 (approximate)	29 000 000	1 000 000	89 200 000	800 000	90 000 000
1921.	28 500 000	2 230 000	79 090 000	2 370 000	81 460 000
1922.	30 000 000	5 000 000	61 050 000	4 500 000	65 550 000
1923.	32 000 000	7 200 000	53 280 000	6 480 000	59 760 000
1924.	32 000 000	9 300 000	47 300 000	8 370 000	55 730 000

As the cost of fuel and electric power is estimated at about 107 400 000 fr. in the 1921 budget, the estimated expenditure of the next few years will undergo an important reduction according to the above calculation. We believe that this calculation has been carefully made. It does not seem impossible that the lowering of prices will make itself felt even more rapidly and more strongly.

6. — Finally, mention must be made of a surplus expenditure required for

accident-assurance as from 1921. This increase results from the fact that the maximum salary insured by the Swiss National Insurance Fund in case of accidents is increased from 4 000 fr. to 6 000 fr.; it is estimated by the Federal Railways at 250 000 fr. per annum.

* * *

Taking into account the above considerations, the financial results of exploitation for the years 1921 to 1924 will probably be somewhat as follows :

TABLE I.

	1921	1922	1923	1924
	Fr.	Fr.	Fr.	Fr.
Working receipts	414 100 000	419 400 000	428 900 000	442 800 000
Working expenditure :				
Working expenditure according to the 1921 budget	379 580 000	379 580 000	379 580 000	379 580 000
Add to or deduct from this expenditure, according to the above calculations, the following amounts :				
1. Extra expenditure after revision of salaries and wages	—	+ 5 000 000	+ 5 000 000	+ 5 000 000
2. Repayment account for cost-of-living bonuses to pensioners, contained in the 1921 budget	— 4 400 000	— 4 400 000	— 4 400 000	— 4 400 000
3. Reduction in expenditure on staff	— 7 000 000	— 8 000 000	— 9 000 000	— 9 000 000
4. Modification of payments to the pensions and benevolent fund :				
a) Wiping out of all payments included in the 1921 budget	— 14 580 000	— 14 580 000	— 14 580 000	— 14 580 000
b) Inclusion of the following sums as payments for the years 1921 and 1924.	+ 13 760 000	+ 13 310 000	+ 13 800 000	+ 15 810 000
5. Reduction in expenditure on fuel and electric power compared with the total of 107 400 000 fr. included in the 1921 budget	— 25 940 000	— 41 850 000	— 47 640 000	— 51 670 000
6. Additional expenditure for accident-insurance premiums	+ 250 000	+ 250 000	+ 250 000	+ 250 000
Estimated working expenditure	341 670 000	329 310 000	323 010 000	320 990 000
Excess of working receipts	72 430 000	90 090 000	105 890 000	121 810 000
Excess according to the report of the 12 March 1920	— 10 600 000	26 600 000	41 500 000	61 000 000

Profit and loss account.

The 1921 budget anticipates for this account an excess expenditure of 48 888 290 fr., including the surplus of working receipts, estimated at 55 851 110 fr. Taking account of surpluses and deficiencies of expenditure, the following new results are arrived at for the years 1921 to 1924 :

TABLE II.

	1921	1922	1923	1924
	Fr.	Fr.	Fr.	Fr.
Balance of profit and loss account for 1921, in round figures	— 48 890 000	— 48 890 000	— 48 890 000	— 48 890 000
The surplus working receipts of 55 850 000 fr. is included in the above balance ; according to the above working accounts, it is increased by the following amounts . . .	+ 16 580 000	+ 34 240 000	+ 50 040 000	+ 65 960 000
The interest on debts will increase as from 1922, by about 6 000 000 fr. per annum consequent on the increase of capital construction, which will reduce the result by .	—	— 6 000 000	— 12 000 000	— 18 000 000
The statutory redemption fund will demand less funds because of the increase of period of repayment from 60 to 100 years; the result, as regards 1921 and succeeding years, will be an approximate saving of. .	+ 10 000 000	+ 10 000 000	+ 10 000 000	+ 10 000 000
Payments on account of renewal fund will have to be increased by the following amounts because of the greater mileage and the increased expenditure on the electric traction of trains.	—	— 500 000	— 500 000	— 500 000
The excess expenditure (1921 to 1923) and receipts (1924) on the profit and loss account, will amount therefore to	— 22 310 000	— 11 150 000	— 1 350 000	+ 8 570 000
Excess according to the report of the 12 March 1920	—101 000 000	— 71 800 000	— 63 900 000	— 50 400 000

According to the above, if the hypotheses which form the basis of the calculations prove to be approximately correct, a balance between receipts and expenditure on the Federal Railways will be attained at the end of 1924, this year indeed giving a slight excess of receipts.

According to the profit and loss account for 1920 the excess of expenditure is about 32 000 000 fr., which will bring the debit balance at the end of the

same year, in round figures, to		fr. 191 000 000
For the succeeding years the following deficits must be added :		
For 1921, in round figures	fr. 22 300 000	
— 1922, — —	11 150 000	
— 1923, —	1 350 000	
		fr. 34 800 000
Total debit balance at the end of 1923, in round figures.		fr. 225 800 000
From which deduct the excess of receipts for 1924		8 570 000
At the end of 1924 *i. e* , when there will again be an excess of receipts, the debit balance of the profit and loss account would then still amount, in round figures, to		fr. 217 230 000
The federal law of the 16 December 1920 modifying article 7 of the Purchase Act by increasing from 60 to 100 years the period fixed for the statutory redemption of the debt, stipulates that the excess of debts redeemed from 1903 to 1919 shall be used to meet in part the debit balance in 1920. The last figure therefore is subject to a reduction by the amount of the excess of debts redeemed at the end of 1919, *i. e.*, in round figures		98 400 000
The *debit balance at the end of 1924 will therefore amount*, in round figures to		fr. 118 830 000

This last amount will have to be redeemed gradually by subsequent surplus receipts.

In their report of the 12 March 1920 the Federal Railways estimated that in the absence of any special means to improve the results, the debit balance would amount to *522 000 000 fr.* at the end of 1924. They then believed it possible to reduce this deficit to 198 000 000 fr. by increased rates and by the temporary suspension of the sinking fund, as well as by the suspension of the yearly redemption of accumulated deficit.

Apart from the raising of railway rates already carried out and the modification of the system of redemption, the reforms in working and the appreciable reduction in the cost of fuel will also probably improve the financial situation. The new calculations show that at the end of 1924 the deficit will be 79 millions less than previously estimated, and indicate that from then onwards the change for the better will continue, so that one may be allowed to look for the gradual elimination of the adverse balance. We are in a position to state in any case that the board of management of the Federal Railways is making every effort to overcome as rapidly as possible the difficulties created by the war and to restore financial equilibrium. As compared with the railways of adjacent countries which are still registering year by year deficits running into milliards of francs, the situation of our Federal Railways may be considered as relatively favourable.

It is to be hoped that the new estimates of the Federal Railways will prove to have been too pessimistic, and that with the general reduction which is setting in, it may also be possible to bring down railways rates. During the war and the period immediately succeeding, railway rates were increased to such an extent that they became an obstacle to the development of traffic. But so long as the profit and loss ac-

counts show deficits it will be impossible to contemplate the lowering of rates on any general scale. All that is possible for the present is the granting of certain concessions likely to encourage traffic without incurring risks as regards the finances of the Federal Railways.

2. — Programme of electrification of the Federal Railways and financial consequences of the substitution of electric traction for steam traction.

The management of the Federal Railways made the following statement on this question in its report of the 5 April 1921 :

« As is known, in 1903 there was constituted a commission of enquiry into electric traction, having as its object the study and definition of the technical and financial considerations inherent in the introduction of electric traction on the Swiss railways. This commission was composed of the most competent Swiss specialists in electrotechnics and railway matters. Their studies were undertaken and carried through on a large scale. It was the unanimous opinion that the introduction of the new system of traction should depend on the result of these enquiries. In 1912 the commission submitted to the board of management of the Federal Railways a report which recapitulated the results of its labours. This report demonstrated that, as regards the point of view of the economy of the project, the electric working of the Gothard Line, with a small volume of traffic such as existed in 1904, would have cost practically the same as steam traction; but that with a heavier traffic, such as will probably be experienced after the introduction of electric working, this method of working will be much cheaper than steam traction. This computation was on the basis of a ton of coal costing 27 fr.

« As regards the steps to be taken to introduce an electric service, it was then generally accepted that it was essential to begin with the Gothard Line, Lucerne-Chiasso, because of the gradient of the Line, of the number of trains, and of the great inconvenience caused by smoke in numerous tunnels; electrification would subsequently be extended in the light of experience gained and in accordance with the prevailing financial conditions.

« Based on the report of the commission of enquiry, the board of management submitted a project to the administrative council, in 1913, accompanied by a request for credit, for the introduction of electric traction on the Erstfeld-Bellinzona section, and, after the conclusion of the procedure connected with the approval of the plans, a start was made, in 1916, with the construction of the hydro-electric works on Lake Ritom.

« A continuous request arose in nearly all quarters for a detailed account respecting the introduction of electric traction. There was scarcely a district served by the Federal Railways whose inhabitants did not wish for information regarding the introduction of electrification, and to know whether account would be taken of the importance of the lines serving that particular district in fixing the order in which the work was to be done. Although the board of management knew that any detailed programme might soon clash with unforeseen circumstances, and would consequently require revision, it could no longer resist the pressure, and in 1918, it submitted the programme asked for to the Administrative Council.

« The report which accompanied this programme stated that the electrification of the Federal Railways would cost at least three-quarters of a milliard fr. It was anticipated that the work would be completed within a period of 30 years, and that the average expense would be 25 million fr. per annum. This figure, however, did not include the cost of

acquiring electric locomotives. Data under this heading could be dispensed with because in the future electric locomotives would be purchased instead of replacing by new ones the steam locomotives which each year become obsolete.

« To obtain information as to the time required for the change, the Federal Railways were divided into three groups, it being understood that the first group should be electrified within the first decade, that is to say between 1919 and 1928.

« Starting from the supposition that the cost of the undertaking would be approximately 50 % higher than it would have been before the war, it was calculated that the total of the annual construction budget of the Federal Railways, including the electrification, would amount to the following sums during the first decade :

Electrification (without the electric locomotives)	fr. 25 000 000
New lines	fr. 4 000 000
Supplementary work	fr. 36 000 000
Rolling stock	fr. 27 000 000
	fr. 92 000 000

« As regards the economical aspect of electric traction, the report of 1918 on the programme of work stated that by reason of the completely changed conditions resulting from the war, the situation had changed in favour of electric traction.

« In 1919, following on the Wettstein report, consideration was given to the possibility of reducing the time required for the execution of the work from 30 to 10-15 years, and the following conclusions were arrived at :

« 1° It is not convenient to reduce from 30 to 10-15 years the period originally contemplated for the electrification of the Federal Railways; it is, however, possible to reduce it to 20 years;

« 2° It will be possible to do this without having to electrify in the first ten years (1919-1928), other lines than those included in group I of the programme; this, however, provided that each year during this period there can be allocated a sum of about 125 million fr. for the constructive work;

« 3° If, subsequently, the same rate of progress is maintained in the electrification of the lines of groups II and III, and if the annual amount in the budget for construction can be maintained at 125 millions, the work may be completed within a further 10 years (instead of 20). It would, however, be premature at the present day to pass an opinion on this point; il will only be wise to do so towards the end of the first decade. The existing conditions and the point of view at that date will make it possible to determine within what space of time groups II and III can be electrified.

« A detailed calculation of the expenditure to be incurred during the next few years (a calculation which it was impossible to make when drawing up the 1918 programme and examining the Wettstein report) has demonstrated that, at present prices, the construction budget of 125 millions will not suffice for future years if the programme is to be adhered to.

« The execution of the 1918 programme (deferred by reason of the year's delay in commencing on the Rupperswil work) would cost (on the prices of Autumn 1920) the following total amounts :

Year.	Total of construction budget.
1922	167 million francs.
1923	191 — —
1924	198 — —
1925	167 — —
1926	143 — —
1927	187 — —
1928	201 — —
1929	179 — —
1930	155 — —
1931	133 — —

i. e., an average, during 10 years, of 172 million fr. as against the 125 millions contemplated at the time of examining the Wettstein report.

« If the electrification were carried out according to this programme, 1 730 km. (1 075 miles) or 60 % of the total lines of the Federal Railways, would be electrified by the end of 1931; further electrification would have begun on an additional 239 km. (149 miles). »

It follows from what has been said that, under existing circumstances, it would have been necessary each year to grant larger sums or to delay the carrying out of the programme.

The year 1921 however, modified the circumstances considerably; the reason was the large and unexpected fall in the price of coal. The rate of interest, on the other hand, has not decreased very appreciably, and there is so far a reduction of about 20 % only in the cost of constructive work and electrical installation. As a result of this reduction of prices the average yearly total of 172 millions for the total construction budgets of the 10 years, 1922 to 1931, is reduced to 138 million fr. If the fall continues the budget will approximate to the 125 million fr. contemplated for the 10 subsequent years, in May 1919, when the Wettstein report was under consideration. The cost of electrification and of rolling stock amounted in this budget to 85 millions, and the other constructional expenses to 40 millions.

Let us examine the economic importance of electrification in conjunction with the Gelpke report, which we have now to consider.

B. — *Report of M. Gelpke, national councillor.*

First of all we quote some explanations drawn from the report dated 8 April 1921, of the board of management of the Federal Railways :

Results of working the Gothard Line by electric traction.

« The author doubtless means by the « results of working » on which he desires information, the experience gained with the new electric traction installations on the Gothard Line both at first and subsequently. According to the report submitted to the Chambers in support, this experience was not of a favourable nature, and the installation was in certain respects inadequate; it would appear that there had been lack of foresight and considerable unwarranted expenditure.

« It would be surprising if an installation of so complicated a nature as that for electric traction on the Gothard Line, with so many essential novel elements, and which further had to be put in under the effect of war conditions and also concurrently with the continuation of steam traction, could be carried out without encountering difficulties and without necessitating alterations or additions. It would be still more surprising to find the employees already familiarised, in the case of such a large innovation, with the special installation and with the methods of preventing or diminishing irregularities of working. It is, however, well known that electric working on the Gothard Line began on certain sections from the middle of September 1920, with remarkable regularity and order, and without the slightest hitch. Regular electric working, on the whole of the Erstfeld-Biasca mountain section, was begun towards the middle of December 1920, *i. e.*, only one month after the date anticipated in the working programme of the Federal Railways for 1919. The extension as far as Bellinzona was delayed until the 4 April 1921 because of the alteration at this station. Judging then by external results, which

are obvious to anyone, it cannot be said that the new installation and the electric working of the Gothard Line are unsatisfactory.

« These considerations on the so far very satisfactory condition of the electric installation of the Gothard Line, both general and particular, might certainly be regarded as reassuring. It will, however, be well to examine briefly the facts mentioned by the author of the report, and the several real difficulties which it has either been possible to avoid without disturbing the train service, or which still remain to be overcome.

« The contact lines which extend over 220 km. (137 miles) of permanent way, 28 km. (17.4 miles) of which are in tunnels, as well as through numerous stations, have only required adjustment at one unimportant point. This was in a spiral tunnel on the Southern slope, as the result of defective work at the time of installation. The isolated cases of damage occurring to these lines result almost exclusively from the fact that, concurrently with electric traction it was necessary to continue steam traction for a certain period, and this, as is known, causes much smoke on the Gothard Line.

« Certain defects were discovered in the turbines, generators and transformers of the Ritom works, some during the preliminary trials and some during actual working; the makers have been obliged to make good these defects at their own cost in view of the guarantees which they gave. When once these imperfections have been overcome, the installation will do credit to the designers, because not only was the type quite novel, but the conditions were particularly severe. The defects did not cause any noticeable interruption in the service or delay in the running of the trains.

« The sub-stations or transforming stations at present in use, are working without any difficulty worthy of note.

« The high-tension feeder cables gave rise to appreciable difficulties noted by the author, although here again the train service was not materially disturbed. Such difficulties were, moreover, anticipated; they were inherent in the nature of the undertaking, for it was impossible to do without cables. They were annoying in that they greatly delayed the work of the cable contractors, and because the working trials had to take place after electric traction had been begun.

« The point involved here is not really such irregularities as had been foreseen, but rather those unforeseen, for they were largely due to the use by one of the cable contractors of unsuitable material in the filling of cable joint boxes. The contractor replaced this material at his own cost. The cables themselves appear to be of good quality. Some trouble was occasioned in the working of the high-tension cables through damage caused at the time of the rearrangement of the tracks during the alteration of the stations at Göschenen and Airolo.

« It has been stated further, that leakages occur from the electrical conductors to such an extent, that the 15 000 volts pressure at the contact wire is reduced to not more than 7 500 volts. This statement however is based on a misapprehension which may be explained in a few words. The board of management of the Federal Railways had already indicated, in 1913, in its report to the administrative council, that the pressure on the contact line should not reach 15 000 volts until the closing down of steam working between Erstfeld and Bellinzona, but should remain at 7 500 volts until then. The pressure on the contact line on the St. Gothard section has not, therefore, since the introduction of electric traction, exceeded 7 500 volts as originally proposed, and this has doubtless made it necessary to avoid as far as possible certain loads

and certain groupings of trains while a sub-station was out of service due to interruptions caused by the traffic. The use of low tension during the transition of steam traction to electric traction should be regarded as the opposite to a lack of foresight. As the insulators were covered with soot, the Federal Railways considered, in fact, that it was necessary in order that steam traction might be replaced by electric traction without dislocation of traffic. This object was completely attained.

« The insulators will be cleaned when steam locomotives are no longer running, and 15 000 volts pressure will be introduced during the course of the Summer.

« The author of the report has also remarked that electric traction does not really begin at Erstfeld, because at that place a steam locomotive is run behind an electric locomotive. If this is the result of a personal observation made by him during a journey on the Gothard Line, it is merely because occasionally, to compensate for the absence of a special vehicle for warming the trains, a small steam locomotive was placed on the train behind the electric locomotive, thus helping at the same time to propel as well as heat the train. The only reason for this is because sufficient warming coaches were not always available, and because, in fact it was not possible to procure all the electric heating which might have been desired.

« These various criticisms, and several others put forward to support the report, have already been answered in the Chambers themselves by the head of the railway department. »

The management of district No. V. makes the following statement in its 4th quarterly report for 1920 on the trials carried out up to the present with electric locomotives :

« On the introduction of electric traction on a section it has constantly been found that there are numerous delays caused by the heavy wear on the contact strips of the bows; this wear results from bad contact between the bow and the conductor, due to the latter being covered with soot resulting from steam traction. There were very few cases of interruption of working arising out of other defects in the locomotives, although defects, inherent in locomotives of new type, might have been fairly numerous.

« To summarise, it may be said that the change from steam traction to electric traction on the Erstfeld-Biasca section has on the whole been satisfactorily effected, and without causing much inconvenience. Experience so far with the new system is absolutely satisfactory, and encourages the hope that it will shortly be possible to overcome the difficulties inseparable from every innovation. »

Comparison of costs of traction.

It may be remarked in the first place that the electric working of the Gothard Line began about 15 September on the Göschenen-Airolo section, and that afterwards it was extended by stages to other sections, until finally, towards the middle of December 1920, the whole of the Erstfeld-Biasca line was run on the new system of traction. But the mixed system (*i. e.*, electricity and steam), such as was in use during this transitional period, can in no way serve as a basis for comparative calculations; it must rather be assumed, for the sake of convenience, that the average traffic of the months of October 1920 to January 1921 was entirely run either on steam or on electricity.

For reasons which it is easy to understand the result of these calculations is scarcely favourable to electric working. Also it cannot help to form an opinion as to the economy of this system of traction. It must be considered as still less decisive as regards the continuation of electrification. The principal error

which impairs these calculations is, on the one hand, the fact that a comparison is made between the future price of coal and the net price of electric power, which is substituted for the expenditure on fuel and which has been excessively high as a result of the war; and, on the other, the limitation of this comparison to a period of time when electricity was only just beginning to replace steam, and when the whole service had not, and could not yet have been adapted to the new conditions. It will not, therefore, be possible to arrive at the cost of electric working until the net price of electric power can be exactly ascertained and the organisation of the service has been completely adapted to the entirely changed conditions.

A calculation made by the Federal Railways, taking into account, as nearly as possible, the above factors, shows that, as regards the section Erstfeld-Biasca, electric energy taken by the locomotives, should cost, per month :

With coal at	150	fr. per ton.	415 140 fr.
—	110	— —	312 840 —
—	70	— —	210 540 —

if the total cost of steam traction and of electric traction respectively are to balance. The figures for expenditure as regards electric power are in respect of traffic during the months of October 1920 to January 1921, or rather of the 1 731 900 units of curent consumed per month on the average by the electric locomotives engaged in this traffic. The cost per unit would then work out at :

$$\frac{415\,140}{1\,731\,900} = 24\text{c.}0 \qquad \frac{312\,840}{1\,731\,900} = 18\text{c.}1 \qquad \frac{210\,540}{1\,731\,900} = 12\text{c.}2$$

at the rate of 150 / 110 / 70 per ton of coal.

As regards these figures, the net cost of electric power taken from the contact line, that is to say by the bow, amounts, according to the calculations of the Federal Railways, with interest at 6 %, and presuming the works give full output to a maximum of 13 c. per unit.

The traffic dealt with from October 1920 to January 1921 amounted per month on the average to :

Passengers . . .	9 126 000	km. tons gross.
Goods	19 922 000	— —

According to figures issued by the Federal Railways, this traffic would have required monthly the consumption of 2 588 t. of coal, which would have cost :

At 150 fr. per ton	388 200 fr.
— 110 — —	284 700 —
— 70 — —	181 200 —

whereas the cost of electric power would have been 225 150 fr. per month.

Assuming that the prices of coal were 150 and 110 fr. per ton, the saving effected, therefore, is 163 050 fr. and 59 550 fr., while at 70 fr. per ton the excess expenditure amounts to 43 950 fr. per month. A comparative calculation must not, however, be confined to the cost of power; it must also take into account the reduction of expenditure effected with electric traction under the heading of personnel and material, as well as of the extra charges it entails for the special service of heating wagons, for interest and sinking fund in respect of the new installations, locomotives and heating wagons.

The final result is that electric traction on the Erstfeld-Biasca section (assuming the price of coal to be 150 and 110 fr. per ton) is 189 990 fr. or 87 690 fr. cheaper per month than steam traction; but with coal at 70 fr. per ton it works out, at the most, at 14 610 fr. dearer, other conditions being equal.

It may be remarked further that if the comparative calculation deals with the cost of current taken from the contact line, it must consider the cost of the coal loaded on the locomotives. Accord-

ing to the calculations of the Federal Railways, coal becomes dearer from the frontier towards the points of consumption in central Switzerland, assuming a rate of interest of 6 %, by from 8 to 12 fr. per ton, according to the purchase price. The cost of coal should be increased by these amounts in the comparative calculations if the price at the frontier is to be taken as 150, 110 and 70 fr., in other words, the net cost at the frontier should not be fixed in the above mentioned calculations at more than about 138, 100 and 62 fr.

It must be added that the traffic in question is very small in comparison with that before the war, and that the economy of electric working would be much more evident in the calculations were based on a larger traffic. In steam traction, the consumption of coal increases almost proportionately to the traffic, that is to say, to the gross kilometric ton carried; with electric traction, on the other hand, the net total cost of electric power remains almost the same up to the point when the station is giving its full output.

C. — *Recapitulation.*

We must again point out that the choice of the present moment of general crisis to carry out such investigations is in the highest degree unfavourable. All the calculations as regards the future are based on estimates and suppositions; not a single figure can be given without some reservation, and not one can be used for subsequent calculations or conclusions unless it is stated exactly on what hypotheses it is based.

The basis of all the calculations is the total quantity of traffic to be carried and its increase in the years to come. The outlook changes according as the estimation of this increase is optimistic or pessimistic. The rate of interest, the cost of material and wages vary, and if in this respect a drop takes place to-day, no-one can say with certainty, still less prove, what these factors will be in the very immediate future, to say nothing of what they will be in 10 years or more. The experience gained during recent months demonstrates this uncertainty in a striking manner. We are of opinion that the action to be taken must not be influenced by these circumstances. We would recall the fact that, whereas during the war the most violent reproaches were levelled at the Federal Railways at meetings or in the press because of a supposed delay in electrification, the programme drawn up in June 1918, by the board of management for the alteration of the Federal Railway system contemplated a period of 30 years, and that this had to be reduced to 20 years consequent on the Wettstein report which was accepted without comment by the States Council in September 1919. By this very report, the Federal Council was to be invited so to act that the electrification of the Federal Railways should be carried out within a period of not more than 10 to 15 years. We would recall, further, the fact that the shortage of coal during the years 1917-1919 compelled our steam worked railways to reduce their train service five times, and that the price of coal became about seven times higher than the pre-war price. At the time of the deliberations on the federal law of the 2 October 1919, regarding the assistance to be given to private railways and steamship lines to facilitate the adoption of electric working, the opinion was even expressed that a subsidy should not be contemplated for these undertakings if the result would be to delay appreciably the electrification of the Federal Railways.

At the present day there is opposition to electrification because this operation would not, it is stated, be advantageous. Such a state of vacillation of opinion as regards the necessity for electrification

is of the greatest detriment to the undertaking.

The electrification of the Federal Railways is an economic necessity, and ought to be brought about if regular working at all times and under all conditions is to be assured. We must not for ever remain dependent on foreign countries, which may withhold their coal, or at any rate dictate their prices without consideration for us. Of the total imports in 1920 (approximately 991 700 t.), 303 914 t., or 30.5 % came from England, and 553 986 t., or 55.9 %, from America, while our former principal sources, Belgium, the Sarre territory and the Ruhr Valley, only delivered to us altogether 65 500 t., or 6.6 %. This fact shows on what casual conditions our coal supply, and consequently the working of our railways, depends, without taking into account the disturbing factors arising out of strikes, transport difficulties, etc.

There is justification, also, for insisting on the fact that the electrification of our railways will make our train service more reliable, and therefore tend to encourage traffic and swell the receipts. It is not true to state that electric working does not give an increase of speed, and therefore a fuller train service. As a matter of fact, the net time taken for the Erstfeld-Biasca journey and *vice versa* is already, in the case of certain trains, shortened by 25′ in the new time-table of 1 June 1921, in which the electric service is included; and there is no doubt whatever that this acceleration will become more marked when this form of service is completely established.

In view of the considerable amount of money involved, it goes without saying that the progress of the extension of electrification to the other groups of railways must be examined very carefully. On the other hand, it is only reasonable that the progress to be made should be regulated by circumstances, the programme for electrification must not be abandoned each thime there is a change in the cost of coal and raw material.

The future extension of electrification must be effected on the same principle as is followed in the execution of work at present in progress, that is to say, when a power station is erected the whole work of electrification must be undertaken (feeders, sub-stations, contact wires, etc.), making possible in each case the complete utilisation of the power station; for the natural result of the incomplete utilisation of a power station is an increase in the cost of working the railway group which depends on it.

As the electrification programme has been drawn up on the basis of a certain increase of traffic, which may not, perhaps, be immediately realised to the extent expected, it may be that some lines, which it was originally intended should form part of a group to be electrified later, will be attached to an existing power station.

It may further be permitted to draw special attention to the fact that the electrification of our railways gives work to the country, and that of the money expended in this connection approximately three-quarters remains in the country. To this may be added the fact that the contribution to be paid to foreign countries to meet our yearly needs in coal, amounting, according to the traffic, to 500 000—700 000 t., is reduced, with each ton saved, by the purchase price of that ton.

We arrive, therefore, with the board of management, at the conclusion that the electrification of the Federal Railways must not be suspended; it must on the contrary be persued in a systematic manner, following more or less the programme of July 1918. As regards the rate of progress, the responsible authorities must have complete liberty to adapt this to circumstances. In any case, the power station at Ritom must

be completed, the stations at Amsteg and la Barberine, the construction of which has been begun, must be carried through, and the lines which will be worked by electricity derived from these stations must be equipped.

It may be hoped that, in the meantime the situation will again become clear and stable, so that questions regarding traffic, the possibility of raising capital, and the establishment of new power stations and their net cost, may be so simplified that it will be possible to continue the work on a basis of assured facts. The annual budgets which the administrative council of the Federal Railways must draw up, and which must be submitted to the Federal Chambers for approval, will indicate to the board of management the available resources.

Consequently, we have the honour to propose to you :

1° To consider and approve this report;

2° To dispense with the formation of a new programme of electrification at present, and to authorise the continuation of the work in the manner suggested above and in conformity with the annual budget.

Berne, 7 June 1921.

On behalf of the Swiss Federal Council :

SCHULTHESS

President of the Confederation.

STEIGER

Chancellor of the Confederation.

MISCELLANEOUS INFORMATION

[625 .242 (.73)]

1. — 100-ton coal cars for the Chesapeake & Ohio.

Figs. 1 to 6, pp. 289 to 291.

(*Railway Age*).

The Chesapeake & Ohio handles a very large amount of export coal from the West Virginia and eastern Kentucky fields. The total tonnage which this road dumped at Newport News in 1920 was 7 264 000 tons, which was exceeded only by the Norfolk & Western. The pier is equipped with a pair of stationary turn-over car dumpers, each of which is capable of handling all sizes of cars up to those of 100 tons capacity at a rate of 30 cars an hour. The coal is dumped from the road cars into special transfer hopper cars which are lifted by an elevator, run along the pier and dumped into pockets. A large part of the export coal has been handled hitherto in hopper bottom cars of 70 tons capacity, but there has been considerable difficulty in preventing these cars from being loaded for interchange points.

To facilitate the handling of tidewater traffic, the Chesapeake & Ohio last year ordered 1 000 cars of 100 tons capacity, of which 500 were built by the Pressed Steel Car Company and 500 by the Standard Steel Car Company. These cars are of the flat-bottom, high-side, gondola type and ordinarily will be unloaded by car dumpers. They are provided, however, with four drop doors which permit them to be unloaded in case of emergency at points where dumpers are not installed.

Of the three large roads which deliver coal to points on Hampton Roads, the Chesapeake & Ohio and the Norfolk & Western recently have adopted cars of 100 tons capacity, while the Virginian is using cars of 120 tons capacity. Both of these designs have been described in previous issues of the *Railway Age*.

Construction of the new cars.

The inside dimensions of the new 100 ton capacity cars are 43 ft. 3 in. long, 10 ft. 1 1/2 in. wide and 7 ft. 5 1/2 in. deep. This gives a coal space of 3 212 cubic feet when level full, or 3 703 cubic feet when heaped at an angle of 30°. Using a factor of 54 lb. per cubic foot, the heaped load would weigh 200 000 lb. The cars, however, are stenciled as of 182 000 lb. capacity to provide for a 10 % overload. The length over striking castings is 44 ft. 7 1/2 in.; the maximum outside width is 10 ft. 3 5/8 in., and the height from top of rail to top of sides is 11 feet. The distance from center to center of the trucks is 30 ft. 7 1/2 in. and the trucks, which are of the Lewis six-wheel type, have a wheelbase of 9 feet. The light weight of the car is 68 300 lb. and the weight on each axle with the car loaded is 44 717 lb.

The center sills are made up of two 12-inch, 35-lb. channels with flanges facing out and reinforced at the bottom by 3 1/2 by 3 1/2 inches by 3/8-inch angles, extending between the draft gears, and at the top by the 1/4-inch floor plates. There is also a reinforcement in the center of the car on top of the floor plates consisting of a 1/4 inch plate 20 inches wide and extending slightly beyond the door openings.

The body bolsters are of cast steel. They are in one piece, 30 inches deep, located inside of the car body and reaching from side to side of the car on top of the floor. The body center plates are of cast steel, 16 inches in diameter, and have machined bearing surfaces. The body bolster center braces are of cast steel machined and the center brace brackets are also of cast steel. The body side bearings are open-hearth steel bars, 4 inches by 5/8 inch by 16 inches, spaced 22 inches from the center of the car to the center of the side bearings, and with a clearance of 1/4 inch between body and truck side bearings.

The side sheets, placed outside the side stakes as in the Virginian 120-ton cars to give the maximum width inside the body, are of

Fig. 1. — Chesapeake & Ohio Gondola coal car of 100 tons capacity.

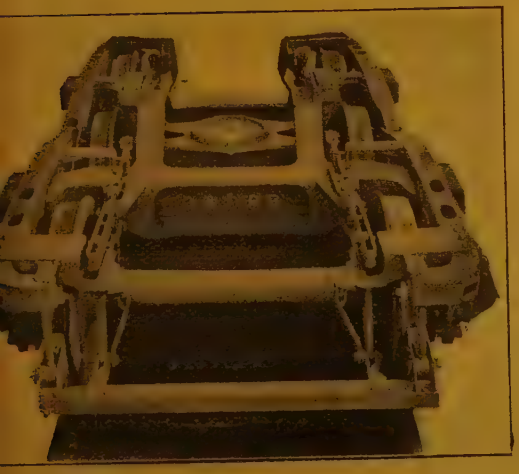


Fig. 2.
Lewis truck with clasp brake.

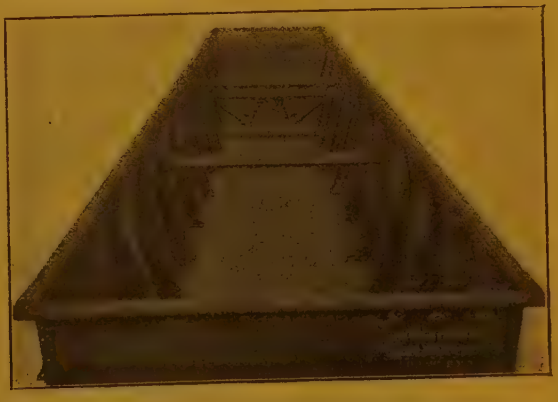


Fig. 3. — Interior of car body, showing bolster, gusset side stakes and crossbraces.

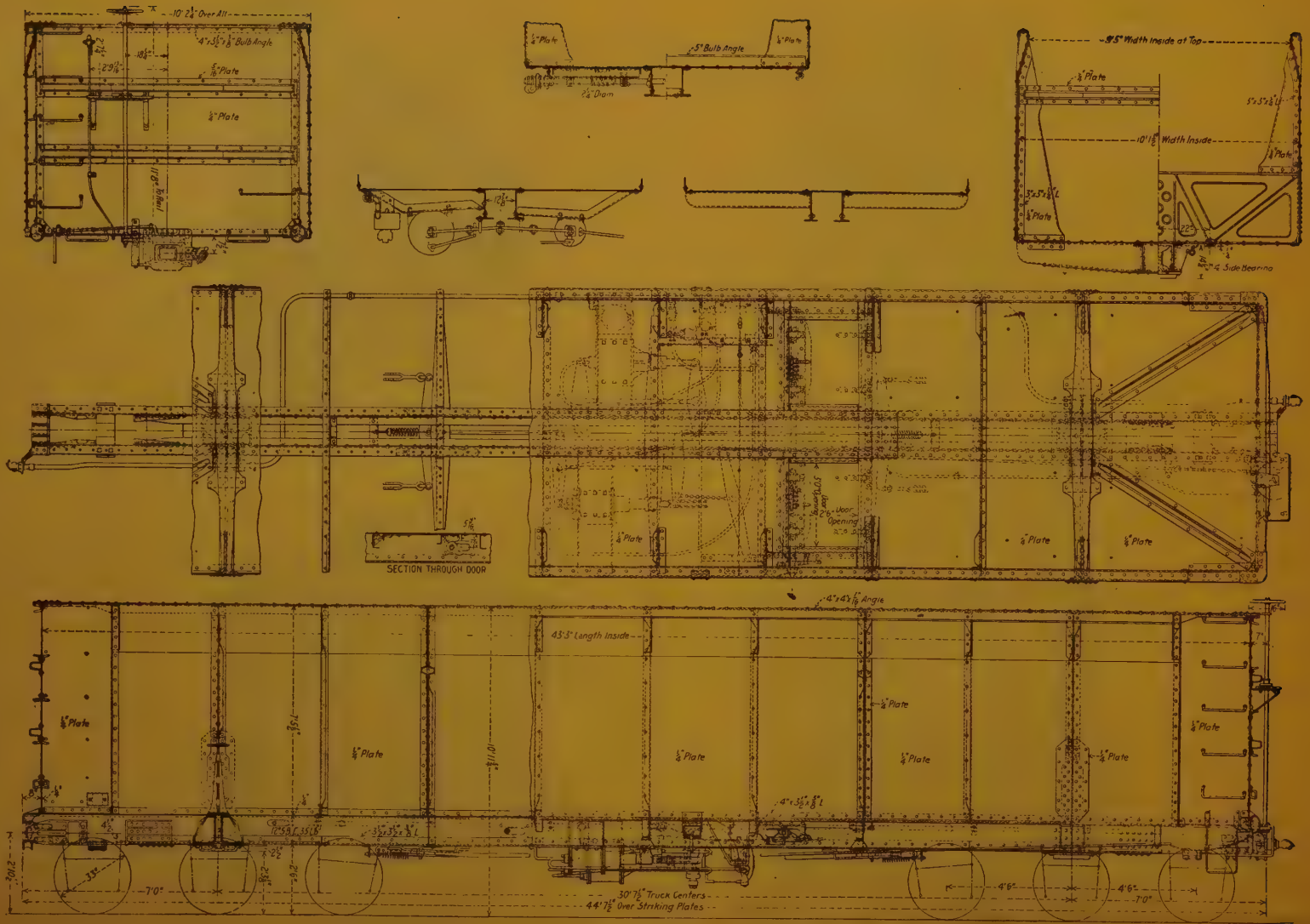


Fig. 4. — Plan, side and end elevations and sections of car body.

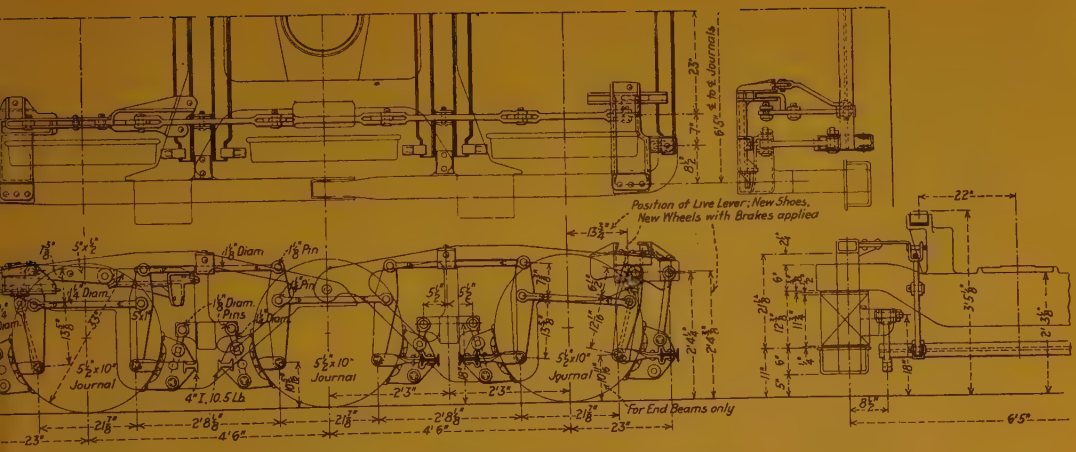


Fig. 5. — Clasp brake for Lewis six-wheel truck.

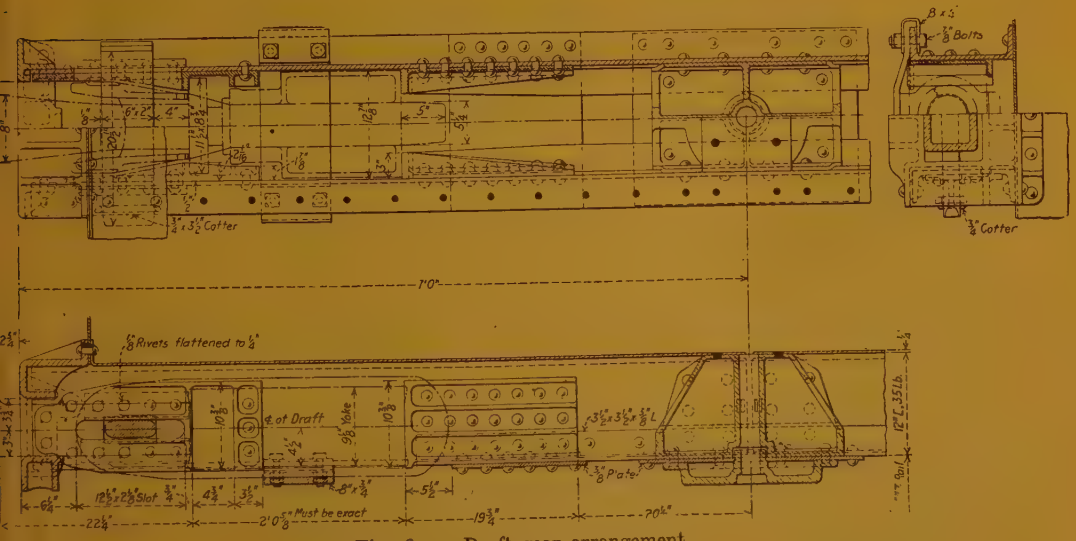


Fig. 6. — Draft gear arrangement.

1/4 inch steel pressed in toward the top and reinforced by a 4 by 4 inches by 7/16 inch angle and at the bottom by a 4 by 3 1/2 inches by 3/8 inch angle. Each side is also reinforced by nine 1/4 inch pressed steel gusset side stakes located inside of the car. The sides are further stiffened on the outside at the top by four cast steel braces and by seven pressed steel braces, as will be noted from the illustration showing the side view of the car. The side sheets are set in at the ends to bring the grab irons inside of the outer face of the side sheets and are flanged over the end sheets. Reinforcing plates are provided at the ends of the body bolsters. The two sides are tied together by two crossbraces, one at each intermediate gusset brace. They are constructed of 1/4 inch pressed plates, are of box shape

and are shown clearly in the illustration of the inside of the car. Such braces were not used on the Norfolk & Western or on the Virginian cars, but should add materially to the stiffness of the sides.

The ends are of 1/4 inch steel sheets, reinforced at the top by a 4 by 3 1/2 inches by 3/8 inch bulb angle and by two pressed steel U-shaped horizontal stiffeners of 5/16 inch steel, 5 inches deep at the center.

There are three cross-bearers, one at the center of the car and the others intermediate between the center and body bolsters, consisting of 1/4 inch pressed steel diaphragms with 8 inches by 1/2 inch bottom tie plates, four crossties : two of pressed steel next to the center cross-bearers and two of 5 inch, 9.3 lb. bulb angles on top of the floor next to the body bolsters: and a diagonal brace to each corner of 1/4 inch pressed steel riveted to the top of the floor. The floor is made of 1/4 inch open-hearth steel sheets.

The large capacity coal cars used on the Norfolk & Western and on the Virginian are not provided with bottom doors, it being assumed that they would always be emptied by car dumpers. The Chesapeake & Ohio cars have flush bottoms but are equipped with emergency drop doors which can be used when necessary to unload the car at a point where car dumpers are not available. The four drop doors, each with an opening of 2 ft. 6 in. by 3 feet, are located as shown on the drawings. They are operated in two sets. Part of the cars are equipped with door operating mechanism designed by the Pressed Steel Car Company and part from the design of the Standard Steel Car Company.

RAILROAD.	Chesapeake & Ohio.	Norfolk & Western	Virginian.
Capacity, stencilled	182 000 lb.	200 000 lb.	218 000 lb.
Capacity, heaped 30°	200 000 lb.	200 000 lb.	240 000 lb.
Cubic capacity level	3 212 cubic feet.	3 122.5 cubic feet	3 850 cubic feet.
Cubic capacity, heaped 30°	3 703 cubic feet.	3 636 cubic feet	4 450 cubic feet.
Estimated density of load	54 lb. per cubic foot.	55 lb. per cubic foot.	54 lb. per cubic foot.
Length over striking plates	44 ft. 7 1/2 in.	43 ft. 9 in.	50 ft. 8 3/4 in.
Coupled length	47 ft. 1 in.	46 ft. 2 in.	53 ft. 3 1 2 in.
Truck centers	30 ft. 7 1/2 in.	31 ft. 8 in.	36 ft. 10 3/4 in.
Truck wheelbase	9 ft. 0 in.	8 ft. 6 in.	8 ft. 8 in.
Height, rail to top of car side	11 ft. 0 in.	11 ft. 0 in.	11 ft. 0 in.
Length, inside	43 ft. 3 in.	42 ft. 7 in.	49 ft. 6 in.
Width, inside	10 ft. 1 1/2 in.	9 ft. 6 in.	10 ft. 2 3/4 in.
Depth, inside, center	7 ft. 5 1/2 in.	8 ft. 6 1/4 in.	8 ft. 5 1,8 in.
Depth, inside, ends.	7 ft. 5 1,2 in.	7 ft. 5 3/4 in.	7 ft. 4 1/4 in.
Width outside, extreme	10 ft. 3 5/8 in.	10 ft. 1 1/4 in.	10 ft. 3 1/4 in.
Weight of car body	41 100 lb.	29 020 lb.	43 200 lb.
Weight of two trucks	27 200 lb.	24 480 lb.	35 700 lb.
Weight of empty car	68 300 lb.	53 500 lb.	78 900 lb.
Weight loaded	268 300 lb.	253 500 lb.	318 900 lb.
Per cent revenue load of total weight.	74.6 %.	78.9 %.	75.3 %.
Raid load per axle, loaded car	44 717 lb.	42 250 lb.	53 100 lb.
Weight loaded per foot coupled length.	5 695 lb.	5 490 lb.	5 985 lb.

The trucks are of the Lewis, six-wheel type with cast steel side frames and bolsters designed and furnished by the American Steel Foundries. The wheelbase is 9 feet and the journals are 5 1/2 by 10 inches, M. C. B. standard dimensions. The wheels are of wrought steel, part of them furnished by the Carnegie Steel Company and part by the Forged Steel Wheel Company. The side bearings consist of pockets cast integral with the truck bolster with cast steel filler blocks and three 3/16 inch shim in each pocket for adjusting the side bearing clearance to the nominal amount of 1/4 inch. The journal boxes are of pressed steel, Kensington type, manufactured by the Union Spring & Manufacturing Company.

The cars are equipped with Westinghouse empty and load brakes, schedule KDE-4-10-16, having a 4-inch take-up cylinder, a 10-inch cylinder for use when the car is empty and an additional 16-inch cylinder for use when the car is loaded. The brakes are of the same type as those used on the Virginian as described in the *Railway Age* of 17 June 1921. Retaining valves are of the 10-20 lb. spring type.

The brake rigging is designed to give a braking effort of 40 % on the empty car and also 40 % on the loaded car. The trucks are equipped with clasp brakes having vertical levers. The brake beams are of 4-inch, 10 1/2-lb. I-beams with two sets of open-hearth forged steel brake beam fulcrums spaced on 3 ft. 10 in. centers and substantial malleable iron brake heads. The hand brake is of the geared and multiplying type. The wheel load is 5 692 lb. on the empty car and 22 358 lb. on the loaded car. The nominal brake shoe pressures are 2 277 lb. on the empty car and 8 943 lb. on the loaded car.

The draft gear is of the Miner A-18-S friction type with 2 3/4 inches clearance between the coupler horn and the striking castings. The cheek castings are of cast steel; each rear cheek has 27 7/8-inch rivets; the front ones have 15 rivets. The draft sill tie is 8 inches by 3/4 inch. The couplers are A. R. A. type D with 6 by 8 inches shanks, connected by keys to cast steel yokes. The striking irons are of cast steel, the coupler carrier iron being cast integral with the striking casting.

In addition to the usual safety devices, the cars are provided with an inside ladder at each end.

The accompanying table gives the principal dimensions and other data of these cars and in addition similar information in regard to the large capacity coal cars used on the Norfolk & Western and on the Virginian.

[624 .138 (.73)]

2. — A novel cinder disposal plant.

Figs. 7 and 8, p. 294.

(*Railway Age.*)

At the engine terminal of the Akron, Canton & Youngstown at Brittain, Ohio, is an ash handling system which presents a number of interesting features in ash disposal at cinder pits. Essentially, the system at this point consists of a depressed pit below a track where the engines may be « spotted » and dumped before entering the roundhouse, and a steam discharging arrangement by means of which the ashes may be removed from the pit and discharged into a cinder car. The cinder pit, which is constructed of concrete, extends 12 feet (inside dimension) along the track and about 10 feet to one side and is divided into two compartments by a concrete wall which extends entirely across the pit parallel to the track except for a vertical opening of 2 1/2 feet at the center; the cross-section in the drawing is taken through this opening.

The compartment thus formed, which is below the track, is so constructed that the three outside walls of the pit slope from their tops to the bottom of the opening in the cross partition, while the other compartment has a level bottom which makes it possible for a man to rake the ashes from below the track, through the opening in the partition and over the trap of the ash-handling arrangement; the

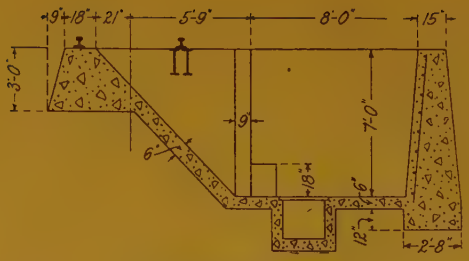


Fig 7. — Cross-section through the cinder pit.

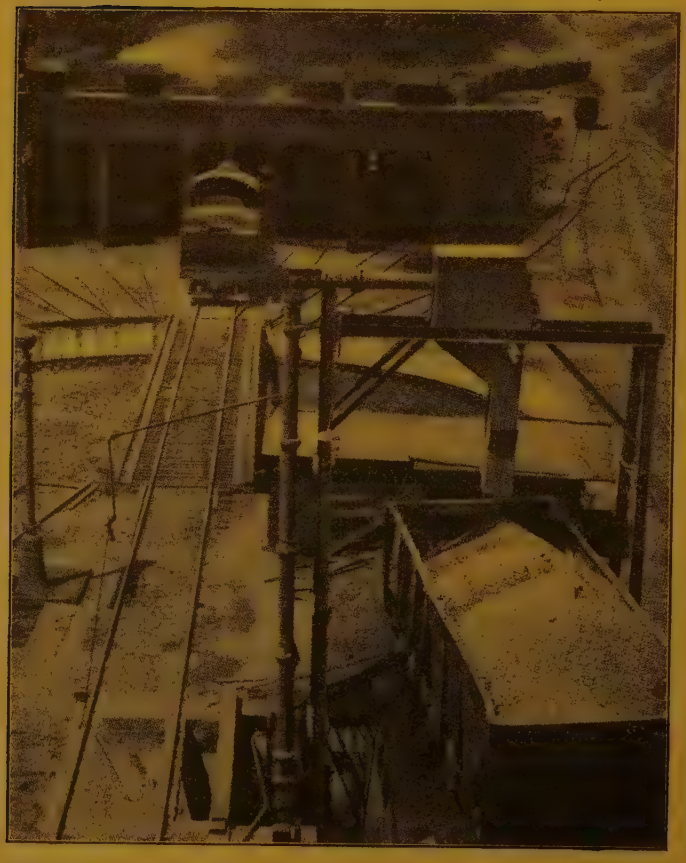


Fig. 8. — A view of the cinder plant at Brittain.

latter is similar to the equipment installed in power plants, etc., whereby ashes and cinders are removed by the force of steam injected into that end of the pipe line below the floor. The steam for operating this system is obtained from the engines on the cinder track, each locomotive being equipped with a quick-acting screw connection in the steam dome.

This plant was put in operation in January 1921, and is reported to be giving satisfactory service. Originally, it was intended that the cinders should be discharged from the pit immediately upon being dumped, but it was found that the pit afforded a sufficient capacity to permit the dumping of about three locomotives before cleaning of the pit was required. With respect to the operation of the installation, it was found that the complete cycle of dumping ashes and removing them from the pit required from 15 to 25 minutes, distributed as follows : 10 minutes for « pulling » the fire, five minutes for blowing the cinders and from two to three minutes for connecting and disconnecting the steam connection to the engine. The operation of blowing the cinders out of the pit and into a cinder car, requires considerable steam, but the amount of steam remaining in the locomotive has always been sufficient to move the engine into the roundhouse. In operating the system it has been found best not to wet down the cinders while in the pit, the established practice being to spray the water into the pipe conveyor near the upper end, thus killing any fire remaining in the ashes and coals.

The ash conveyor system is a product of the Conveyor's Corporation of America, Chicago, Ill. We are indebted for the information and illustrations of this equipment to S. S. Senter, chief engineer of the Akron, Canton & Youngstown.

[656 .253]

3. — The « Daniels » automatic train-stop.

Figs. 9 to 11, p.296.

(*Railway Gazette.*)

Opinion is still divided as to whether automatic train-stop apparatus should be exclusively mechanical or whether electrical appliances may be included, either on the track alone or on the engine also, and it remains to be seen which type will eventually meet with practical approval. Meanwhile, many inventors have attempted to solve the problem, and attention may now be given to a purely mechanical installation devised by Mr. J. J. Daniels, which has been the subject of trial on a section of the Great Eastern Railway. In common with other train-stop apparatus, this necessarily operates on the normal danger principle, so that any failure or breakdown tends to cause the brakes to be applied, but in many respects the apparatus includes features of a more or less novel character, which may prove of great value under practical conditions.

The main principle is that, without interfering with existing equipment, so that the present responsibility of a driver is maintained, at both distant and essential stop signals, two curved ramps, designated « interceptors », are fitted, one fixed — its purpose being to cause a short whistle or other audible warning indicating that a signal is being passed, no other action occuring if the signal is « clear »; the other movable, and designed to cause at a « distant » signal a continued whistle to sound and the brakes to be partially applied, or, at the stop signal, a full brake application to be given, with which may be associated the mechanical closing of the regulator or the cutting off of current in the case of electric trains. Under the locomotive are three « pendulum » counterbalanced levers, each having a rubber-tyred contact wheel, the centre one designed to co-operate with the movable interceptor at « stop » signals, those on either side co-acting with the movable interceptor at

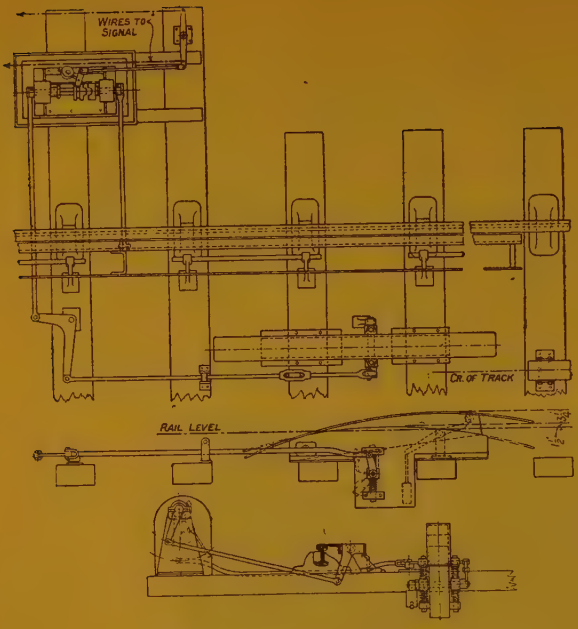
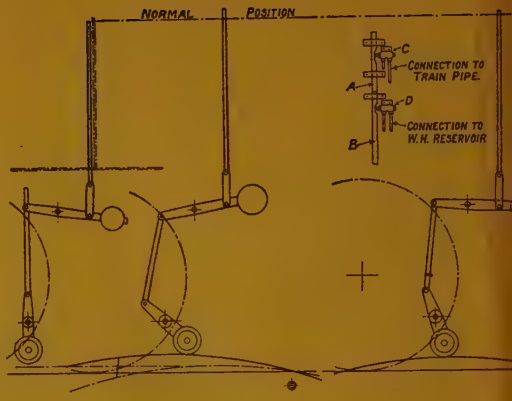


Fig. 9. — Track mechanism.

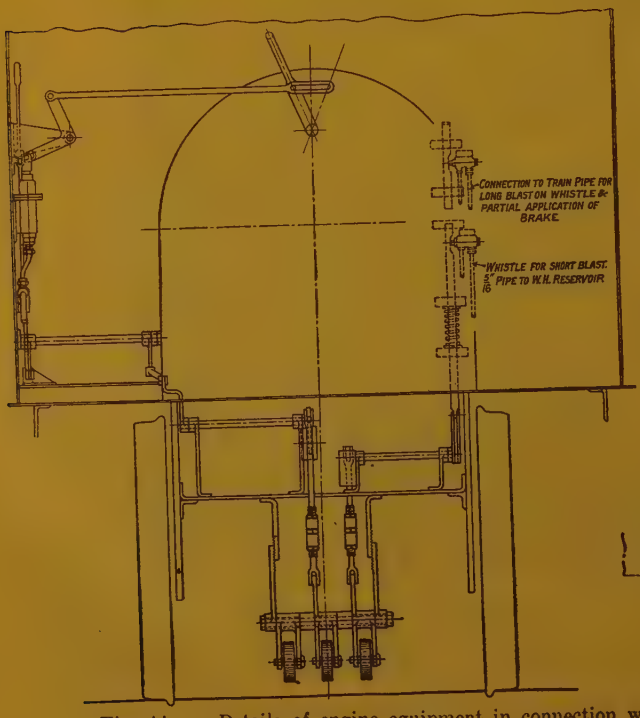


Normal position.

Contact with raised interceptor. Distant signal in « danger » position.

Contact with fixed intercep Distant signal in « clear » positi

Fig. 10. — Main operating features.


CONNECTION TO TRAIN PIPE FOR LONG BLAST ON WHISTLE & PARTIAL APPLICATION OF BRAKE.
WHISTLE FOR SHORT BLAST.
PIPE TO W.H. RESERVOIR

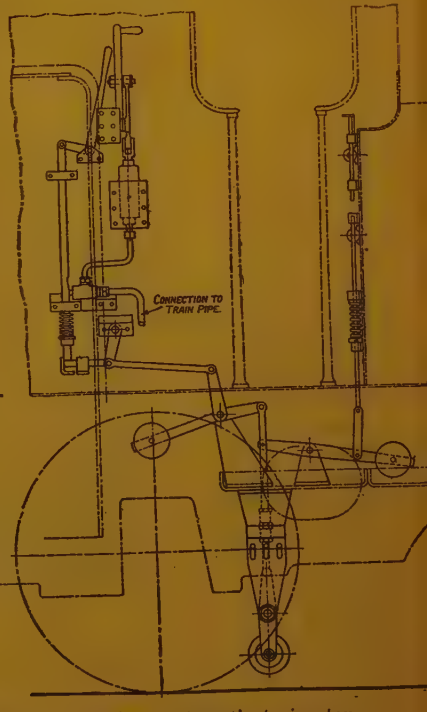


Fig. 11. — Details of engine equipment in connection with « Daniels » automatic train stop.

« distant » signals, which are placed to one side of the centre line of the track, and in line with the fixed interceptor at all signals concerned. It is necessary to provide two pendulum levers for distant signal operation, to allow for engines working either way round. The movable interceptors normally occupy a raised position within a sand and snowproof case, so as to act upon the corresponding pendulum lever or levers, but, when the signal is « clear », are lowered by an approaching engine so that they do not influence the engine mechanism. The fixed interceptors operate every time, the purpose being, as already mentioned, to indicate that a signal is being passed thus serving as a « clear » indication when the signal is « off » and the movable interceptors are inoperative. The interceptors are placed, with reference to each signal, at suitable positions according to the normal running speeds and traffic conditions.

The mechanism as a whole possesses considerable interest, and principal attention may be directed to the means whereby the movable interceptors are operated when required by the train under signal control, without adding to the strain upon the signal mechanism or to the physical demands upon the signalman. Also to the system of pendulum counterbalanced levers, so that the violence of impact is very slight, thus meeting one of the chief objections to mechanical devices on engines designed to come in contact at widely varying speeds with apparatus on the track.

Figure 9 illustrates the track mechanism. This involves a clutch device fitted outside the track, but which only requires two longer sleepers to carry it, the treadle bar, which can be that required for ordinary lock and block working or can be utilised for general signalling requirements, and the supports and connections for the interceptor. The clutch is connected by a wire and one or more levers, as required, to the bell crank of the signal concerned, its only purpose being to engage or disengage the operating mechanism, so that no appreciable strain is placed upon the signal connections or the physical demand upon the signalman added to. The actual movement of the movable interceptor is effected through the agency of the treadle as it is acted upon by the leading wheels of the engine, ss that if the signal is « clear » and the clutch engaged, the ramp is lowered in advance of and by the engine itself, so as to be inoperative. If the clutch is disengaged, the signal being at « danger », the interceptor, of course, remains in its operative position and acts upon the engine mechanism. The mechanical connections, as will be seen, are of a simple character, and can be easily attended to by the usual roadmen.

In the case of a « distant » signal, the movable interceptor is placed to one side of the centre line, so that one of the outside pendulum levers only is acted upon, and the lift given by the curved surface of the interceptor when in its operative position is designed to cause only a continuous blast of the whistle and a partial brake application. Having received the warning the driver can then reset the apparatus and run under control to the stop signal if that still remains adverse. For the « stop » signal, however, the movable interceptor is centrally arranged, and causes a full brake application. The fixed interceptors are placed to one side of the centre line in every case, as they operate on the same mechanism as is used at distant signals.

Figure 10 shows the main operating features apart from the mechanical details of the mechanism upon the locomotive. In the first position the pendulum lever, with its rubber-tyred contact wheel, hangs loosely, the lowest point of the wheel being designed to come well below the working level of a fixed interceptor, or of a movable interceptor in its raised position. On coming in contact with a fixed interceptor, as shown in the third position, the pendulum lever is swung upon its fulcrum, its pendulum action adding its degree of momentum, so that a sufficient movement is ensured to raise the rod B a given distance, which is regulated by a spring surrounding it, causing a whistle supplied from the air brake system to sound momentarily through the medium of valve D. Rod B immediately falls, the fixed interceptor having been « cleared », and the whistle valve D which has been opened during the rise and fall of rod B is

held open a sufficient time to cause a distinct though momentary sounding of the warning whistle.

In the case of a distant signal, a higher lift is given by the movable interceptor when in its raised position, so that the lifting of rod B causes rod A to rise to its fullest extent, so as to act upon a valve C, which causes a partial application of the brakes. As the rod A cannot fall, due to a cam surface formed upon it adjacent to its engagement with valve C, the whistle continues to sound, though it can be released by the driver pressing upon its head to return it to its normal position. This action necessarily releases the brakes at the same time, but the driver has had definite warning that he has passed a distant signal at « danger », and it is upon his own responsibility that he proceeds without bringing his train under control. At a stop signal the action is more decisive, as will be seen from reference to figure 11, which shows the engine equipment.

The arrangement of the three pendulum levers is clearly indicated, those to either side which apply to distant signals and the fixed interceptors at all signals being connected, as shown, with the two valves already mentioned. Rod B is preferably fitted with a spring to overcome the inertia due to the varying impact of the contact wheels of the pendulum levers, due to the different speeds at which contact may be made. The lower valve provides for the short whistle to indicate that a signal is being passed, while the upper valve causes a prolonged sound and a partial application of the brakes, as described. The centre contact wheel and pendulum lever acts through the mechanism indicated, first upon a valve which causes a full application of the brakes, and through that an air cylinder is supplied with air to cause, through the bell crank lever and link shown, the regulator to be moved to its closed position. The link engagement with the regulator handle is slotted, so that ordinary operation of the regulator handle is not interfered with. A re-setting lever is provided by which normal conditions can be restored after a train has been pulled up by the train-stop apparatus.

The apparatus in essentials is simple in design and construction, and specially skilled attention is not called for either in regard to the track apparatus or for the maintenance of the engine apparatus. As it is designed as a « safety » adjunct to existing signalling equipment it does not interfere with, or require any modification of, standard plant. If it is not thought necessary to provide the air cylinder and connections for closing the regulator, the full application of the brakes, being regarded as sufficient control, the cost of equipment is correspondingly reduced. As the contact of the rollers on the pendulum levers is momentary and relatively very slight, and the movable interceptors are balanced and fitted with shock-absorbing springs, the effect of repeated blows at high speed is minimised. The pendulum levers will operate on either side of the vertical, according to the direction of travel.

The apparatus has been installed for some time for experiment and demonstration at the up « distant » and up « home » signals at Bruce Grove station, on the Enfield branch of the Great Eastern Railway. Recently we attended trials and demonstration of the « Daniels » train-stop, when (although this was the first occasion on which the engine had been used for other than yard trials) the various tests operated most satisfactorily. Trial runs included : 1° both signals « clear », in which case only the signal-passing warning whistle was given; 2° the « distant » signal at « danger », in which case the warning whistle continued to sound until released and the brakes were partially applied, but as the « home » signal was « cleared » in time no further action occurred beyond the signal-passing whistle; and 3° a partial brake application and warning whistle on passing the « distant » signal at « danger », followed by a full application and compulsory stoppage at the « home » signal.

Mr. Daniels has devised several adjuncts to his apparatus to meet particular applications, as in the case of several stop arms governing the approach to a large station or junction to cause the movable interceptor to be lowered when any one of the signals concerned is

« clear », the others remaining at « danger »; also to meet the conditions which apply on single lines, or where both direction movements have to be taken into account; for shunting and wrong-road working, etc.

The test trips were carried out exactly to schedule and without interfering with the regular 10-minute service of trains running on the section concerned at the time. The engine was a 0-6-0 tank engine, as used regularly on the Enfield branch, and ran bunker first for the test journeys, though it was designed to work equally well either way. As the movable interceptors are enclosed the apparatus is fully protected from usual climatic influences. Indeed, it would act equally well were the line flooded sufficiently to cause total immersion of the interceptors and clutches.

[385 .589 (.481)]

4. — Withdrawal of the Norwegian provisional legislation regarding compulsory arbitration.

An emergency Act, instituting compulsory conciliation in labour disputes, was promulgated in Norway on the 6 August 1915.

Based on the Australian, New Zealand and Canadian laws, this Act laid down a complete procedure of conciliation, in connection with which the country was divided into a certain number of arbitration districts.

All differences which could not be settled amicably were to be notified to « conciliators » nominated by the Crown. Cessation of work was illegal so long as the conciliation proceedings were in progress. At least four days must elapse between notification to the « conciliator » and the declaration of a strike or lock-out. Strikes and lock-outs were forbidden as a general rule up to the expiration of the notice fixed for the breaking of contracts, such notice ordinarily extending to fourteen days. Either party could demand that the conciliation proceedings should be terminated fourteen days after the notice of cessation of work had been given.

In cases where negotiations failed to secure an agreement, the conciliator had the right to summon witnesses, and to demand the production of all relevant documents; he could further lay the matter before the public by issuing a report.

Illegal cessation of work incurred the imposition of fines amounting to from 5 000 to 25 000 Crowns.

These measures, which were coldly received by the employers, provoked active opposition on the part of the employees. As to compulsory arbitration, which had been proposed at the same time as compulsory conciliation, both employers and employed were wholly hostile; the articles of the bill having reference thereto had accordingly to be withdrawn.

In 1916 a new bill on the subject of compulsory arbitration was laid before the Storthing, which adopted it practically without opposition. Compulsory arbitration was limited to a certain number of cases.

The King could decide to impose it in any case in which a difference between trades union and employer or group of employers appeared to him to be of such a nature as seriously to threaten the interests of the community. If arbitration were resorted to cessation of work became illegal. The arbitration tribunal, consisting of a president, two members nominated by the Crown, and two other members nominated respectively by the employers' and workers' organisations, made its decisions by majority vote. The duration of the validity of their decision was not to exceed three years, unless with the consent of both parties.

The Act, which was renewable from year to year, expired this year in April. The Government decided not to renew it.

After having been applied twice in 1916, it was applied for the third time at the end of March 1920, on the break-down of negotiations between the shipowners and engineers, during a dispute which led to the stoppage of the whole of the coastal navigation.

M. Peschaud.

[385 .113 (.73)]

5. — American Railway results for June 1921.

The latest statistics of the « Interstate Commerce Commission » reproduced in the *Journal of Commerce* of 11 August, shew that the financial situation of the American railways has improved considerably during the month of June.

Dealing with 202 « first class roads », that is to say, with the lines of general interest, this statement shews that the net revenue from traffic has risen, during the month under consideration, to $51 778 000 that is to say $14 697 346 more than in May, and compared to a deficit of $14 612 000 in June 1920.

This is the first time that the railways have recorded a similar result since November 1920, when their earnings reached $54 343 793, and must be taken as a sign of their recovery. In spite of this, however, the earnings since the beginning of the year do not represent more than 3.1 % of the total capital value of the railways, so that in order to bring them up to the normal of 6 %, $47 295 000 are still required to reach this percentage.

The working coefficient has fallen from 85.43 % in May to 82.34 % in June; in 1920 it was for the same two months 95.69 % and 96.84 %.

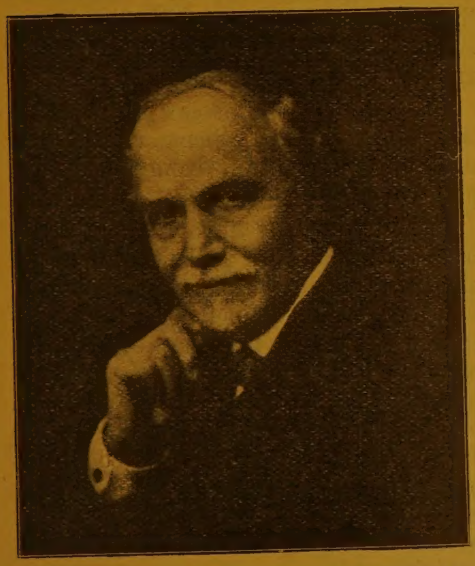
The traffic receipts, $ 461 127 000, are less by 8.7 % than those of June 1920, due no doubt to the influence of the economic crisis. On the other hand, the working expenses, $379 688 000, are 20 % less, and the difference will without doubt become more and more perceptible during the following months, during which the two great reforms recently achieved, namely, reduction of wages and the release from Government control, will have had time to produce their full effects.

M. Peschaud.

OBITUARY

ALBERT SARTIAUX,

Chief Engineer of Bridges and Highways;
Honorary Chief of the Traffic Department and Consulting Engineer to the French Northern Railway;
Member of the Permanent Commission of the International Railway Association;
Delegate at the Sessions at Brusse's (1885), Milan (1887), Paris (1889 and 1900), Washington (1905) and Berne (1910).



We have been deeply affected by the news of the death of Mr. Albert Sartiaux, one of the most distinguished and kindly disposed of the French members of the Permanent Commission of our Association.

The deceased had achieved great prominence in the railway world, not only in France, but also in other countries, and his untiring energy had led him into many spheres of activity.

He always took a very keen interest in our Association of which he was nominated as a member of the Permanent Commission at the meeting at the end of the sixth session (Paris 1900).

Mr. Albert Sartiaux's outstanding characteristics were a remarkable capacity for work, a very clear and accurate mind and a wonderful gift of exposition. He was always ready to consider any new ideas, and all his dealings were marked by the greatest courtesy.

No one took a greater part than he did in the progress which has been achieved in railway matters between 1875 and the present time.

Among the ideas which are due to his initiative, or which he put to practical purposes may be mentioned the use of electricity for lighting and for moving wagons in station yards, the introduction of the block system into France (1883), the enlargement in the capacity of wagons, the introduction and application of continuous brakes, cab signalling, additional lines through stations, increase in siding accommodation where required, improvements in regularising the use of rolling stock, etc.

He also took a prominent part in the promotion and development of the metre gauge railways, both for commercial traffic and for military purposes.

Mr. Albert Sartiaux was born at Cateau-Cambrésis in 1845.

Entering the Polytechnic School in 1864, he became a « Student engineer of bridges and highways » in 1866. He was duly promoted to be an « Engineer of bridges and highways » and then in 1885, to be « Chief Engineer of the First Class ».

In 1875 he joined the Northern Railway Company as an Engineer in the Traffic Superintendent's Department, and was in due course promoted to Assistant Traffic Superintendent, and afterwards to be Chief of this important department (Exploitation).

He at once manifested the high capabilities that he has always displayed, and was the worthy successor of the eminent engineers of the Northern Company, who since the opening of the line have been responsible for the latest methods of working. It was not until he was handicapped by over-work and ill health that he retired from active duties. The Company, desirous of not entirely loosing his valuable advice, conferred upon him the tittle of Consulting Engineer, in addition to that of Honorary Chief of the Traffic Department.

Since 1910 he was the President of the Managing Committee of the Ceinture Railway.

In addition to being a Director of the Military Railway Technical Services in 1886, and a member of the High Military Commission on Railways of the same year, he was also a Technical Commissionner of the Nord Railway.

As a member of the High Military Commission on Railways, he took part in organising the preparations for the mobilisation and concentration of the railway for military purposes, and made many reports to the High Military Commission on Railways where his influence was very great.

After organising the mobilisation and concentration, he proceeded in August 1914 to the scene of operations, and arranged the withdrawal of nearly all the rolling stock on the Nord and the Nord Belge and Belgian State Railways. Later on at Calais he organised the return to civil conditions in the Nord and Pas-de-Calais districts.

He was always a strong advocate of the use of electricity. He was a member of the High Commission on electricity, President of the Paris Electricity Company, and director of other companies.

Mr. Albert Sartiaux was a supporter of the Channel Tunnel scheme, and in 1880 took up the question from a practical point of view.

In spite of many important duties, he interested himself in philanthropic work, and in education, etc. He was, since 1907, a member of the Council for administrating the relief to the poor of Paris, a member of the Council of the Conservatory of Arts and Sciences since 1905, and of the National School of Mines since 1909. His great ability also led to his being chosen as President of organising committees and of committees of award in connection with various international exhibitions.

Our lamented colleague held the Grand Cross of the Legion of Honour, was a Commander of the Order of Leopold of Belgium, and had received other foreign decorations (English, Russian, Dutch, Danish, Swedish, Spanish, Egyptian, Tunisian, Persian, Chinese and Japanese).

We offer to his son, Mr. Félix Sartiaux, our deepest sympathy and most sincere condolence.

The Executive Committee.

NEW BOOKS AND PUBLICATIONS

[385. (02 & 385. (04]

PEREIRE (GUSTAVE) and JOLIVET (GUSTAVE), engineer of Arts and Manufactures. — **Les chemins de fer de l'avenir (The railways of the future)** — One volume in-4° (10 3/4 × 8 3/4 inches), x + 212 pages with 5 maps, 88 diagrams, and numerous tables in the text. — 1921, Paris, Gauthiers-Villars, Publishers, 55, Quai des Grands-Augustins. — Paper copies : 10 French francs.

In this book, Mr. G. Pereire gives his own personal views on what the railways of the future will be. He endeavours to show the desirability of equiping the railways with rolling stock of ever increasing capacity. This is the principal object of the book, and in the first part a general outline is given of the advantages which such a step would secure for railways and for transport generally.

The second part gives the results of investigations undertaken to determine the maximum dimensions that may be given to rolling-stock of large capacity. The calculations given deal with :

1° Loading gauge, according to the number of lines and the wheel base of the wagons;

2° Maximum dimensions of wagons corresponding to these loading gauges;

3° Methods of solving the problem. Laying down rails on rubble stone ballast, to support very heavy axle loads;

4° Tare and effective load of these wagons according to the strength of the permanent way which has to carry them, that is to say, according to the maximum loads allowed per axle.

The third part of the book deals with the relation between the tare of the wagons and the effective load carried, according to the relations existing between the gauge of the permanent way and the width and length of the wagons. A whole series of formulae has been worked out, and tables have been prepared which are reproduced in the form of interesting graphs.

The result of the latter investigation shows that :

1° In the present state of affairs it would be difficult to improve on the 40 and 50 ton wagons now in use, as far as working on existing lines is concerned, and it would be a mistake to attempt to exceed these sizes.

2° The construction of lines capable of supporting heavier axle loads will make it possible to increase the capacity of the wagons, while preserving a suitable ratio between the tare and the effective load, provided however that the loading gauge is increased.

In other words, to arrive at the ideal type of railway, it is necessary to co-ordinate :

The loading gauge;

The load per metre run which the permanent way will carry;

The maximum axle load.

The fourth and fifth parts deal with methods of construction and cost of the lines and rolling stock of the railways of the future; and finally consideration is given to the question of what arrangements should be made for the construction of these railways.

The most interesting chapter of these two final parts is that in which the author compares his ideal railway with the

canals. He arrives at the following interesting conclusions :

« High capacity railways, capable of coping with an enormously bigger volume of traffic than the canals, and at a cheaper rate, can also more easily reach the centres to be served. »

It is further remarked that « the time required to construct this railway of the future would always be less than in the case of canals ».

It is probable that this book will provide those interested in the subject with a source of new or more practical ideas, which is, as the author himself says, the principal object of the book.

We give below an extract from the table of contents, in order to show the care and method which Mr. G. Pereire has brought to bear on the study of such new and complex problems.

FIRST PART.

On Railways.

Chapters

I. — Situation of the railways before 1914. — The future which may await them.

II. — International railways.

SECOND PART.

Railways of the future. Methods of construction.

Chapters

I. — Loading gauge and width of track.

II. — Dimensions of wagons.

III. — Methods of plotting. — Permanent ways.

THIRD PART.

Ratio of the tare of wagons to the effective load carried, according to relations existing between the gauge of the permanent way, and the width and length of the wagons.

Chapters.

I. — An attempt to formulate a method of determining the probable tare of wagons.

II. — Of the probable weight of wagons of very great capacity.

III. — Rolling-stock for wide loading gauge. Wagons three times the width of the track.

IV. — Special wagons running on two tracks.

FOURTH PART.

Methods of producing and cost of lines and rolling-stock for railways of the future. Comparison with present day methods of transport.

Chapters.

I. — Types of permanent way for very heavy loads. Examples of method of construction. Cost.

II. — Special wagons of very large capacity running on several parallel tracks.

III. — Capacity of lines for heavy traffic Comparison with present day railways and with canals.

FIFTH PART.

How to prepare for laying down the railways of the futurs. General conclusions.

Ch pters.

I. — Handling and warehousing goods.

II. — Junction between coastal and inland lines.

III. — Advantages of a single railway system for great traffic lines. « The joint-companies high capacity railway system. »

J. V.